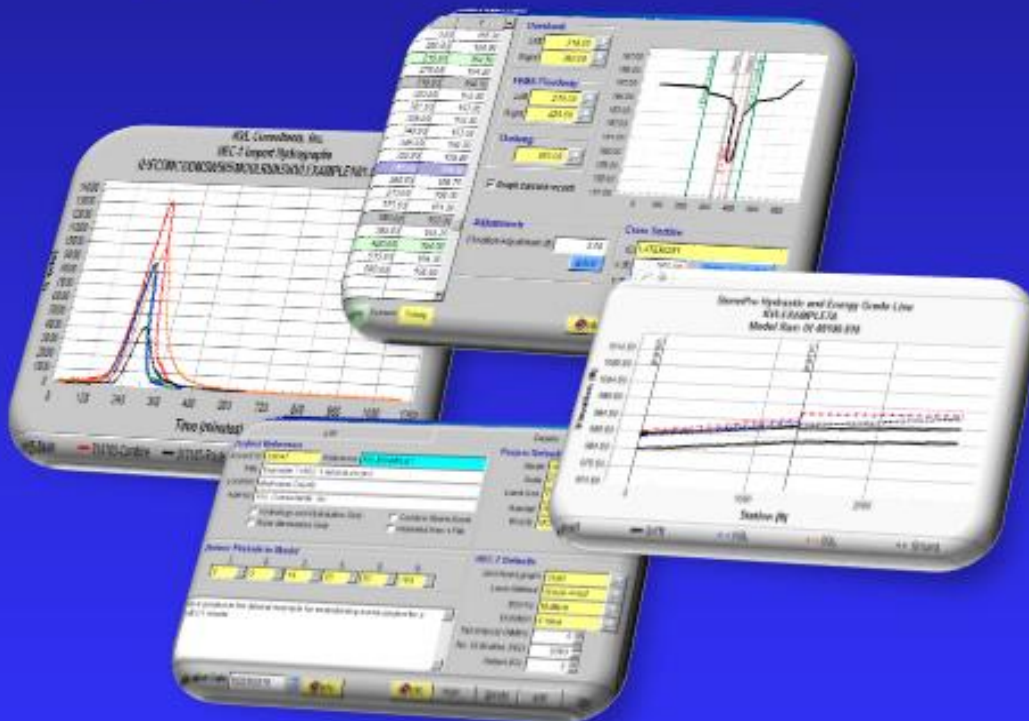




The Flood Control District of Maricopa County
DDMSW Training Workshops
HYDROLOGY and
STORM DRAINAGE HYDRAULICS

June 4, 2019



Maricopa County Department of Transportation (MCDOT)
Computer Training Room
2919 W Durango St, Phoenix, Arizona 85009

Presented by:
Kenneth Lewis, P.E.
KVL Consultants, Inc.

DDMSW Training Workshops

Hydrology and Storm Drainage Hydraulics

Training Dates: June 4, 2019 (Tuesday)
June 11, 2019 (Tuesday)

Location: Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009

Instructor: Kenneth V. Lewis, P.E.
DDMSW Developer

This training class is designed for hydraulic and hydrologic engineers interested in learning DDMSW, an application program that implements District's Drainage Design Methodologies and Standards.

Agenda

8:30 – 9:00	Application Overview <i>System Overview, Program Installation, General Features, Files, Tools, Administration, Help, New Features</i>
9:00 – 9:45	Application Defaults <i>Agency Defaults, Project Defaults, Rainfall, Soils, Land Use</i>
9:45 – 10:00	Morning Break
10:00 – 11:00	HEC-1 Overview <i>Major Basins, Sub-Basins, Diversions, Routing, Storage, Network, Modeling, Graphs</i>
11:00 – 12:00	Rational Method and Storm Drain Overview <i>Major Basins, Sub-Basins, Diversions, Storage, Hydraulics, Network, Modeling, Conveyance Facilities, Street Drainage, StormPro Backwater Modeling</i>
12:00 – 1:00	Lunch Break
1:00 – 2:45	HEC-1 Tutorial
2:45 – 3:00	Afternoon Break
3:00 – 4:30	Rational Method and Storm Drain Tutorial

DDMSW 5.6.0 TRAINING WORKSHOPS

HYDROLOGY AND STORM DRAINAGE HYDRAULICS

**Engineering Application Development and River Mechanics Branch
Engineering Division
Flood Control District of Maricopa County**

June 2019

*This document contains step-by-step tutorials on standard hydrologic methods used by the District that are implemented in **DDMSW**. The tutorials were designed to encapsulate the capabilities and features of **DDMSW** to build hydrologic models such as **HEC-1** and the **Rational Method**. The tutorial for the development of the **HEC-1** model uses the **CLARK UNIT HYDROGRAPH** and the tutorial for the **RATIONAL METHOD** model includes a storm drain example, which is used for the **STORMPRO BACKWATER MODELING** tutorial.*

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Appendix A - DDMSW Users Manual

I. HYDROLOGY AND STORM DRAINAGE HYDRAULICS

1.1 HEC-1 MODELING USING CLARK UNIT HYDROGRAPH

1.1.1 Problem Statement

To estimate the 100-year design discharge using **GIS** data for sub basins, land use, soils and time of concentration with the following given conditions:

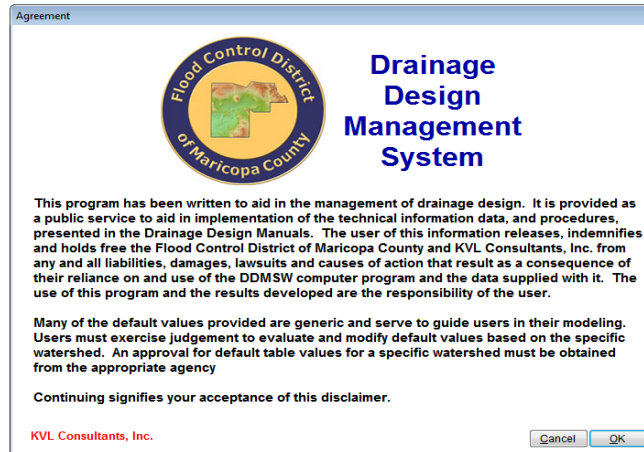
- ❖ HEC-1 Model
- ❖ FCDMC Soils
- ❖ FCDMC Land Use
- ❖ NOAA14 Rainfall
- ❖ MCDOT Roads (not applicable)
- ❖ Clark Unit Hydrograph
- ❖ Green-Ampt Loss Method
- ❖ Single Storm
- ❖ 24-Hour Duration
- ❖ Tab Interval: 5 Minutes
- ❖ Number of Ordinates: 2000
- ❖ Output Level: 5

1.1.2 Step-by-Step Procedures

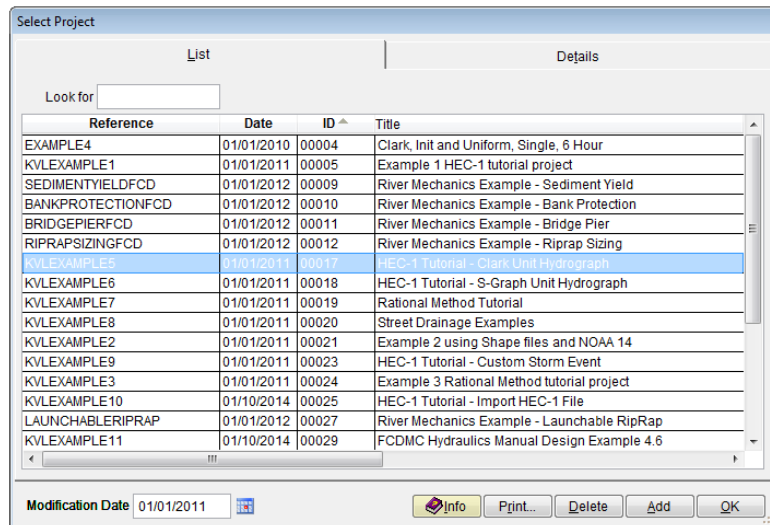
- Step 1: Establish a New Project and Default Set-up.
- Step 2: Set Model Runs Path
- Step 3: Prepare Maps
- Step 4: Establish Rainfall Data from **GIS**
- Step 5: Establish Sub-Basin, Land Use and Soils Data from **GIS**
- Step 6: Review Established Sub-Basin, Land Use and Soils Data
- Step 7: Establish Storage Facilities Data
- Step 8: Establish Routing Data
- Step 9: Develop Hydrology Network
- Step 10: Run **HEC-1** Model
- Step 11: Review Model Results
- Step 12: Backup Project

(A) Step 1 - Establish a New Project and Defaults Set-Up

- (a) Click the **DDMSW** icon on the Desktop or Program menu to launch the **DDMSW**. Click **OK** to accept the software disclaimer as is shown in the following figure.



After the **DDMSW** is launched, the **SELECT PROJECT** window is automatically opened as is shown in the following figure.



- (b) Click the **Add** button on the **SELECT PROJECT** window to start a new project (Or **File** ➔ **New Project** ➔ **Add**).
- (c) On the **NEW PROJECT OPTIONS** form, select **Hydrology and Hydraulics** checkbox and select the **Standard** radio button. Click **OK** to close the form.
- (d) Type “KVLEXAMPLE5A” into the **Reference** textbox. This is the name of the new project. The users can choose the name as long as it does not exist in the **DDMSW** project list.
- (e) Type into the **Title** textbox a brief descriptive title of this project. (*Optional*)


- (f) Type into the **Location** textbox the location of this project. **(Optional)**
- (g) Type into the **Agency** textbox the agency or company name. **(Optional)**
- (h) Type a detailed description of this project into the textbox on the bottom left side of the window. **(Optional)**
- (i) In the **Project Defaults** frame, keep all the default data settings.
- (j) Under **HEC-1 Defaults** frame, change the default **Storms** from “Multiple” to “Single” by clicking on the magnifying glass (Selector button).
- (k) Under **HEC-1 Defaults** frame, change the default **Duration** from “6 Hour” to “24 Hour” by clicking on the magnifying glass (Selector button). Also change the Tab Interval (NMIN) from 5 to 2.
- (l) Click the **Save** button to save the entered data.
- (m) Click the **OK** button on the **SELECT PROJECT** form to close the window. The following figure shows what the window looks like.

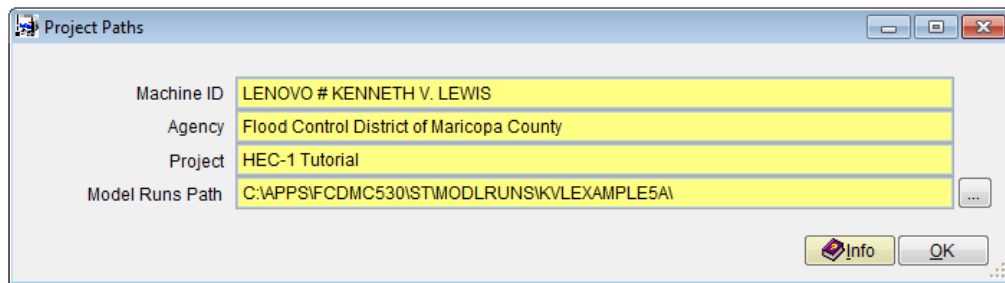
The screenshot shows the 'Select Project' dialog box. The 'Project Reference' section contains: Project ID: 00053, Reference: KVLXAMPLE6A, Title: HEC-1 Tutorial, Location: Maricopa County, Agency: Flood Control District of Maricopa County, and checkboxes for 'Hydrology and Hydraulics Only' (checked) and 'Custom Storm Event' (unchecked). The 'Project Defaults' section contains: Model: HEC1, Soils: FCDMC, Land Use: FCDMC, Rainfall: NOAA14, and Roads: MCDOT. The 'Return Periods to Model' section shows a row of dropdowns with values 2, 5, 10, 25, 50, and 100. The 'HEC-1 Defaults' section contains: Unit Hydrograph: Clark, Loss Method: Green-Ampt, Storms: Single, Duration: 24 Hour, Tab Interval (NMIN): 2, No. Ordinates (NQ): 2000, and Output (IO): 5. The 'Modification Date' is 05/16/2017. Buttons at the bottom include info, Print, Delete, Add, and OK.

Note: The **Project ID** “00053” in the above figure is the database record unique read-only project identifier, which is automatically generated by the program when a new project is created. When users create a new project in this tutorial, the **Project ID** of the new project will not be the same as the **Project ID** shown in the above figure.

(B) Step 2 - Set Model Runs Path

When running the **HEC-1** model in **DDMSW**, the names of the input and output files are automatically established. The basic file format is *XX-YYY* where *XX* is the name of the major basin and *YYY* is the return period. So for Major Basin *01* and Return Period *100-years*, the file name would be *01-100*. The input file uses **.dat* as the file extension and the output file uses **.out* as the extension. Because the file names for all projects are the same, it is necessary to establish unique folders for the model runs for each project.

- (a) From the menu bar of the main application window, click **File** ➔ **Project Paths** to open the **PROJECT PATHS** form.
- (b) Click the browse button  to the right of **Model Runs Path** textbox.
- (c) Navigate to the **"Modlrns"** folder and highlight **"Modlrns"** folder. Click **Make New Folder** button on the **BROWSE FOR FOLDER** form and enter **"KvlExample5A"**.
- (d) After setting the project path, click the **OK** button to close the **BROWSE FOR FOLDER** window.



- (e) Click **Save** and then click **OK** to close the **PROJECT PATHS** window.

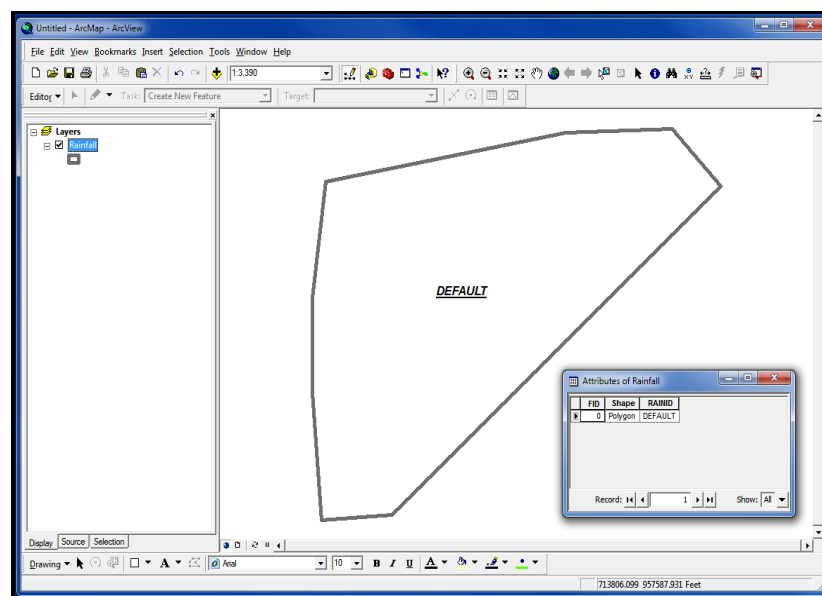
(C) Step 3 - Prepare ESRI Shape Files

This step is only for information purposes. There is no action required for the tutorial user in this step. Several ESRI shape files must be prepared. They are, *Rainfall*, *Sub-Basin*, *LandUse*, *Soils* and *Tc*. As part of the shape files, the table structures must include specific fields. For the purposes of this tutorial, all these shape files have already been prepared. This tutorial does not cover the creation of the shape files. For tutorials on how to create ESRI shape files, please refer to “**HOW TO PREPARE ESRI SHAPE FILES FOR DDMSW**” document that can be downloaded from the District website (<https://www.maricopa.gov/264/How-to-Prepare-ESRI-Shape-Files>).

This section describes the general requirement for the required shape file tables. Assigning file names to the shape files to be used are not critical. For the purpose of this tutorial, however, map files are named based on the data they represent. It is important, however, that field names, data types and formats inside the tables must be fixed as described in the following sections.

(C.1) Rainfall

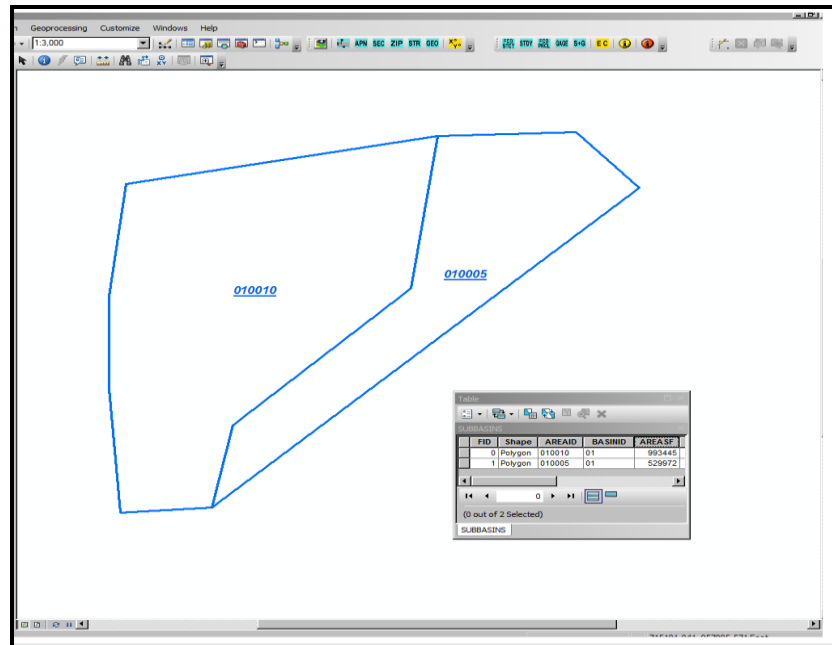
The Rainfall map (*Rainfall.shp*) will contain a single polygon and have a field named **RAINID**, which is defined as Character 8 data type indicating a Text data field of 8 characters long. The Rainfall map can be created after the Sub-Basins map (*Subbasins.shp*) has been prepared and is basically the combined polygon areas of the modeled Sub-Basins.



(C.2) Sub-Basins

The Sub-Basins map (*Subbasins.shp*) will contain one polygon for each Sub-Basin in the project. The required fields include:

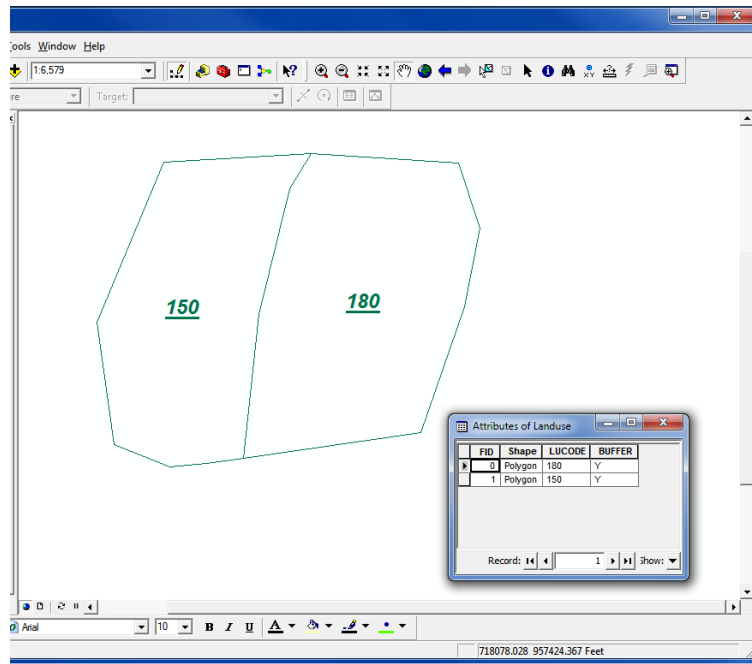
- ❖ **AREAID** Character 6 Enter unique **Sub-Basin ID**
- ❖ **BASINID** Character 2 Enter **Major Basin ID**
- ❖ **AREASF** Numeric 12.0 Data entered into this field will be overwritten internally by **DDMSW**. This field contains the Sub-Basin area in square feet. The data for this field is calculated automatically when the **Update** button is clicked on the **UPDATE HYDROLOGY FROM GIS** form in **DDMSW**.



(C.3) Land Use

The Land Use map (*Landuse.shp*) will contain polygons for land use data. There can be more than one polygon with the same land use ID. It is vitally necessary that the land use coverage extends beyond the extent of all Sub-Basins. The required fields include:

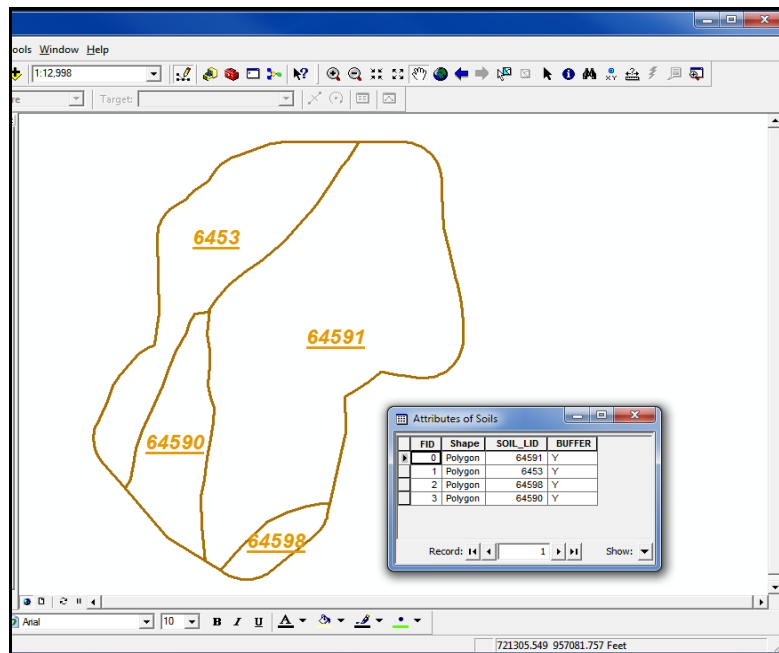
- ❖ **LUCODE** Character 15 **LUCODE** values should be consistent with the values in the **DDMSW** land use defaults table.



(C.4) Soils

The Soils map (*Soils.shp*) will contain polygons for soils data. A **GIS** map for soils data can be obtained from the Flood Control District. There can be more than one polygon with the same Soil ID. It is vitally necessary that the soils coverage extends beyond the extent of all Sub-Basins. The required fields include:

- ❖ **SOIL_LID** Numeric 15 **SOIL_LID** values should be consistent with the values in the **DDMSW** soil defaults table.

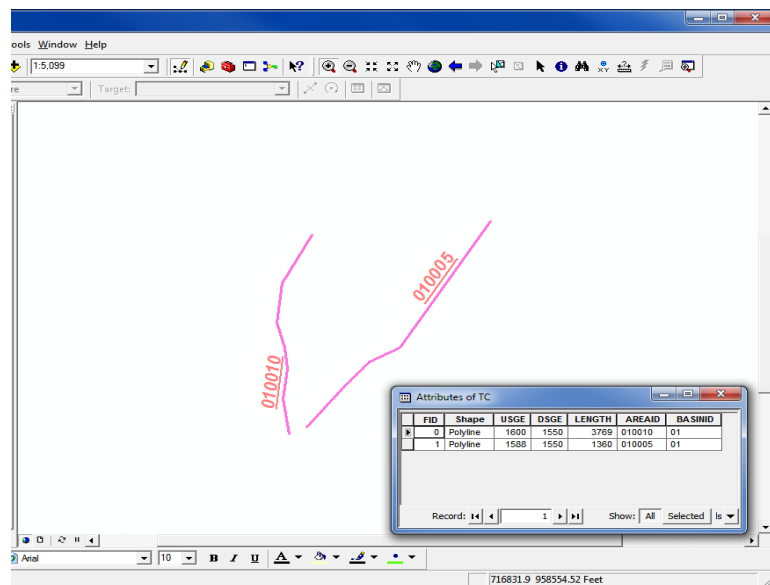


(C.5) Tc

The Time of Concentration map (*TC.shp*) will contain polylines for Tc data. There needs to be one Tc polyline for each Sub-Basin in the project and each polyline must be completely contained within its respective Sub Basin. The required fields include:

- ❖ **AREAID** Character 6 This is determined internally by **DDMSW**.
- ❖ **BASINID** Character 2 This is determined internally by **DDMSW**.
- ❖ **LENGTH** Numeric 12.0 This is determined internally by **DDMSW**.
- ❖ **USGE** Numeric 9.2 Enter the upstream ground elevation.
- ❖ **DSGE** Numeric 9.2 Enter the downstream ground elevation.

The data for **AREAID**, **BASINID** and **LENGTH** are populated automatically when the **Update** button is clicked in the **UPDATE HYDROLOGY FROM GIS** form and any data entered will be over-written.



(D) Step 4 - Establish Rainfall Data from GIS

(D.1) Rainfall Ids

In **DDMSW**, different major basins can have different rainfall data. If there is only one major basin then the program will use the “**DEFAULT**” as rainfall.

- (a) From the menu bar of the main application window, click **Hydrology** → **Rainfall Ids** as shown in the following figure and the **RAINFALL IDS** window opens.

- (b) Select the **Source** (can be “GIS” or “Manual”). Since a rainfall map has been established, select “GIS”.
- (c) Entering **Description** information is optional.
- (d) After the data entry, click the **Save** button.
- (e) Click the **OK** button to close the window.

ID	Source	Description
DEFAULT	GIS	Default NOAA14 rainfall.

Rainfall ID

Rainfall ID: Source:

Description:

Buttons: Info, Print..., Delete, Add, OK

(D.2) Rainfall

- (a) From the menu bar of the main application window, click **Hydrology** → **Rainfall** to open the **NOAA 14 RAINFALL ID: DEFAULT** form.

NOAA 14 Rainfall ID: DEFAULT


Rainfall Map

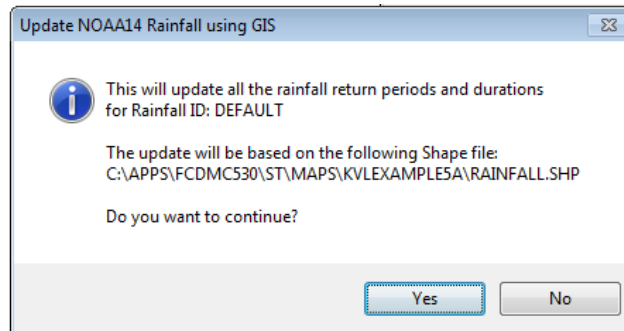
Required Map Fields

Average Rainfall Data for ID: DEFAULT

	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 Min						
10 Min						
15 Min						
30 Min						
1 Hour						
2 Hour						
3 Hour						
6 Hour						
12 Hour						
24 Hour						

Buttons: Log, Info, Print..., Update, Rainfall ID, OK

- (b) Click on the  button at the right side of the **Rainfall Map** textbox and select the *Rainfall* map (*Rainfall.shp*) file established earlier. It may be necessary to migrate to the folder that the shape file is in.
- (c) After selecting the rainfall map, click the **Save** button.
- (d) Click **Update** to create the NOAA14 rainfall data from the **GIS** map. An **UPDATE NOAA14 RAINFALL USING GIS** dialog box similar to the figure below will appear.



- (e) Click the **Yes** to proceed.
- (f) After the update is completed, the **NOAA 14 RAINFALL ID: DEFAULT** form will then have the updated data in the **Average Rainfall Data for ID: DEFAULT** frame as shown below.

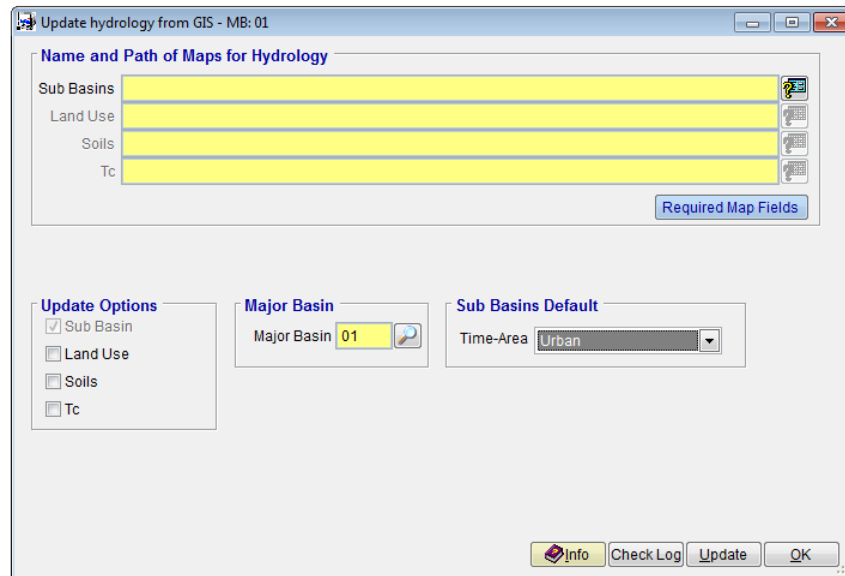
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 Min	0.264	0.357	0.427	0.521	0.593	0.666
10 Min	0.402	0.543	0.650	0.793	0.903	1.015
15 Min	0.499	0.673	0.806	0.983	1.119	1.258
30 Min	0.672	0.907	1.085	1.324	1.507	1.694
1 Hour	0.831	1.122	1.343	1.639	1.865	2.096
2 Hour	0.964	1.281	1.524	1.854	2.102	2.360
3 Hour	1.045	1.365	1.618	1.971	2.252	2.542
6 Hour	1.237	1.577	1.848	2.218	2.505	2.804
12 Hour	1.414	1.784	2.075	2.467	2.768	3.080
24 Hour	1.679	2.174	2.569	3.121	3.559	4.018





- (g) Click the **OK** button to close the window.

(E) Step 5 - Establish Sub-Basin, Land Use and Soils Data from GIS

The project's Sub-Basin, land use and soils data can be populated in **DDMSW** from the maps created earlier.

- (a) From the menu bar of the main application window, click **Maps** → **Update Hydrology** to open the **UPDATE HYDROLOGY FROM GIS** window.



- (b) On the **Update Options** data frame, check the **Land Use**, **Soils** and **Tc** checkboxes.
- (c) In the **Map File Key Field Name** frame, enter "**LUCODE**" for **Land Use Code**.
- (d) In the **Sub Basins Default** frame, select "**Urban**" from the drop-down list items for the **Time-Area**.
- (e) Click the  button to the right of the **Sub Basins** textbox and select the *Sub-Basins* map (*Subbasins.shp*). It may be necessary to migrate to the appropriate folder.
- (f) Click the  button to the right of the **Land Use** textbox and select the *LandUse* map (*Landuse.shp*).
- (g) Click the  button to the right of the **Soils** textbox and select the *Soils* map (*Soils.shp*).
- (h) Click the  button to the right of the **Tc** and select the *Tc* map (*TC.shp*).
- (i) Click **Save**.

Before update, the **UPDATE HYDROLOGY FROM GIS** form should look like the following figure.

- (j) On the form, click **Update**. An **UPDATE HYDROLOGY FROM GIS** dialog box will appear.

- (k) Click **Yes** to continue.
- (l) Click the **OK** button to close the **UPDATE HYDROLOGY FROM GIS** window.

(F) Step 6 - Review Established Sub-Basin, Land Use, and Soils Data

The Sub-Basin, Land Use, Soils, and TC data have been developed from **GIS**. It is necessary to review the data to make sure that all information is correct.

(F.1) Sub-Basins

- (a) From the menu bar of the main application window, click **Hydrology** → **Sub Basins** to open the **SUB BASINS** window. Click the **Details** tab to view the data details for each sub basin.

The forms below show the data for **Sub Basins** "010005" and "010010".

Sub Basins - MB: 01

List **Details**

Sub Basin

Major Basin: 01

Sub Basin: 010005

Sort: 10

Sub Basin Parameters - Clark

Area (sq mi): 0.019

Length (mi): 0.292

USGE (ft): 1588.0

DSGE (ft): 1550.0

Slope (ft/mi): 130.1

Time-Area: Urban

Kb: 0.033

Rainfall Losses - Green-Ampt

	Value	Default	Custom
IA (in)	0.25	0.25	<input type="checkbox"/>
DTHETA	0.29	0.29	<input type="checkbox"/>
PSIF (in)	2.75	2.75	<input type="checkbox"/>
XKSAT	1.339	1.339	<input type="checkbox"/>
RTIMP (%)	43	43	<input type="checkbox"/>
XKSAT (Bare Ground)	0.930		<input type="button" value="Custom"/>
Avg Vegetation (%)	50.0		

Return Period Parameters

	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Custom Tc	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tc (hrs)	0.281	0.263	0.243	0.220	0.207	0.196
Vel (ft/s)	1.51	1.62	1.75	1.93	2.05	2.17
R (hrs)	0.322	0.299	0.274	0.246	0.229	0.216

Info ReSort Print... Delete Add MB Update OK

Sub Basins - MB: 01

List **Details**

Sub Basin

Major Basin: 01

Sub Basin: 010010

Sort: 20

Sub Basin Parameters - Clark

Area (sq mi): 0.036

Length (mi): 0.230

USGE (ft): 1600.0

DSGE (ft): 1550.0

Slope (ft/mi): 217.4

Time-Area: Urban

Kb: 0.031

Rainfall Losses - Green-Ampt

	Value	Default	Custom
IA (in)	0.25	0.25	<input type="checkbox"/>
DTHETA	0.28	0.28	<input type="checkbox"/>
PSIF (in)	3.03	3.03	<input type="checkbox"/>
XKSAT	1.084	1.084	<input type="checkbox"/>
RTIMP (%)	32	32	<input type="checkbox"/>
XKSAT (Bare Ground)	0.753		<input type="button" value="Custom"/>
Avg Vegetation (%)	50.0		

Return Period Parameters

	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Custom Tc	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tc (hrs)	0.222	0.203	0.184	0.166	0.156	0.148
Vel (ft/s)	1.52	1.66	1.83	2.03	2.16	2.28
R (hrs)	0.143	0.129	0.116	0.104	0.097	0.091

Info ReSort Print... Delete Add MB Update OK

(b) Click the **OK** button to close the **SUB BASINS** form.

(F.2) Land Use

(a) From the menu bar of the main application window, click **Hydrology** → **Land Use** to open the **LAND USE** form. Click the **Details** tab to view the land use data details for each record.

The forms below show the data details for **Land Use Codes** “150” and “180” for **Sub Basin** “010005”.

The screenshot shows the 'Land Use - MB: 01' form with the 'Details' tab selected. The 'Land Use' section displays the following data:

Field	Value
Major Basin ID	01
Sub Basin ID	010005
Land Use Code	150
Area (sq mi)	0.0029
Area (%)	15.3
Description	Small Lot Residential - Single Family (4-6 du per acre)

The 'Land Use Data' section contains a table with columns for 'Value', 'Default', and 'Custom'.

Parameter	Value	Default	Custom
Initial Loss (IA)	0.25	0.25	<input type="checkbox"/>
Percent Impervious (RTIMP)	30	30	<input type="checkbox"/>
Vegetation Cover	50.0	50.0	<input type="checkbox"/>
Moisture Deficit (DTHETA)	NORMAL	NORMAL	<input type="checkbox"/>
Resistance Coefficient (Kb)	MIN	MIN	<input type="checkbox"/>

At the bottom of the form are buttons for Info, Copy, Print..., Delete, Add, MB, and OK.

The screenshot shows the 'Land Use - MB: 01' form with the 'Details' tab selected. The 'Land Use' section displays the following data:

Field	Value
Major Basin ID	01
Sub Basin ID	010005
Land Use Code	180
Area (sq mi)	0.0161
Area (%)	84.7
Description	High Density Residential - Multi Family (10-15 du per acre)

The 'Land Use Data' section contains a table with columns for 'Value', 'Default', and 'Custom'.

Parameter	Value	Default	Custom
Initial Loss (IA)	0.25	0.25	<input type="checkbox"/>
Percent Impervious (RTIMP)	45	45	<input type="checkbox"/>
Vegetation Cover	50.0	50.0	<input type="checkbox"/>
Moisture Deficit (DTHETA)	NORMAL	NORMAL	<input type="checkbox"/>
Resistance Coefficient (Kb)	MIN	MIN	<input type="checkbox"/>

At the bottom of the form are buttons for Info, Copy, Print..., Delete, Add, MB, and OK.

(b) Click the **OK** button to close the **LAND USE** form.

(F.3) Soils

- (a) From the menu bar of the main application window, click **Hydrology** → **Soils** to open the **SOILS** form.

The form below shows the data details for **Soil ID** “64591” for **Sub Basin** “010005”.

The screenshot shows the 'Soils - MB: 01' application window. It has two tabs: 'List' and 'Details'. The 'Details' tab is active. The form is divided into three main sections: 'Sub Basin', 'Soil Data', and 'Soil Description'. The 'Sub Basin' section contains fields for Major Basin ID (01), Sub Basin ID (010005), Soil ID (64591), Area (sq mi) (0.0190), and Area (%) (100.0). The 'Soil Data' section has a table with columns 'Value', 'Default', and 'Custom'. It contains three rows: 'XKSAT' with values 0.930 and 0.930, 'Rock Outcrop (%)' with an empty field, and 'Effective (%)' with the value 100. The 'Soil Description' section has fields for Book Number (645), Map Unit (91), and a description text box containing 'Momoli-Carrizo complex'. At the bottom, there is a toolbar with buttons for Info, Copy, Print..., Delete, Add, MB, and OK.

Value	Default	Custom
XKSAT	0.930	0.930
Rock Outcrop (%)		
Effective (%)	100	

Further, the forms below show the data details for **Soil IDs** “64590” and “64591” for **Sub Basin** “010010”.

The screenshot shows the 'Soils - MB: 01' application window. It has two tabs: 'List' and 'Details'. The 'Details' tab is active. The form is divided into three main sections: 'Sub Basin', 'Soil Data', and 'Soil Description'. The 'Sub Basin' section contains fields for Major Basin ID (01), Sub Basin ID (010010), Soil ID (64590), Area (sq mi) (0.0087), and Area (%) (24.4). The 'Soil Data' section has a table with columns 'Value', 'Default', and 'Custom'. It contains three rows: 'XKSAT' with values 0.390 and 0.390, 'Rock Outcrop (%)' with an empty field, and 'Effective (%)' with the value 100. The 'Soil Description' section has fields for Book Number (645), Map Unit (90), and a description text box containing 'Momoli gravelly sandy loam 1 to 5 percent slopes'. At the bottom, there is a toolbar with buttons for Info, Copy, Print..., Delete, Add, MB, and OK.

Value	Default	Custom
XKSAT	0.390	0.390
Rock Outcrop (%)		
Effective (%)	100	

(b) Click the **OK** button to close the **SOILS** form.

(G) Step 7 - Establish Storage Facilities Data

To enter Storage Facility data, do the following:

- From the menu bar of the main application window, click **Hydrology** → **HEC-1** → **Storage** to open the **HEC-1 STORAGE FACILITIES** form.
- On the **HEC-1 STORAGE FACILITIES** form, click **Add** to add a record.

(c) On the **Details** tab, select “*SL, SS, ST*” on the **Discharge Options** frame.

- (d) Check the following checkboxes in the **Discharge Options** frame. Ignore the Warning messages, if there are.
- **Low-Level Outlet (SL)**
 - **Spillway Characteristics (SS)**
 - **Top of Dam Overflow (ST)**
- (e) For the **Storage ID**, enter “ST0010”.
- (f) For the **Low-Level Outlet (SL)** data card, enter the following:
- **Centerline Elevation:** 96.00
 - **Cross-Section Area:** 4.00
 - **Discharge Coefficient:** 0.70
 - **Orifice Equation Exponent:** 0.50
- (g) For the **Spillway Characteristics (SS)** data card, enter the following:
- **Spillway Crest Elevation:** 98.00
 - **Spillway Length:** 20.00
 - **Discharge Coefficient:** 3.00
 - **Weir Equation Exponent:** 1.50
- (h) For the **Top of Dam Overflow (ST)** data card, enter the following:
- **Elevation Top of Dam:** 100.00
 - **Length Top of Dam:** 50.00
 - **Discharge Coefficient:** 3.00
 - **Weir Equation Exponent:** 1.50
- (i) Click **Save** to save the data entered. After the data entries, the **HEC-1 STORAGE FACILITIES** form should look like the following figure.

HEC-1 Storage Facilities - MB: 01

List Details Storage/Elevation

Storage Facility

MB ID 01

Storage ID ST0010

Discharge Options

SL, SS, ST

Low-Level Outlet (SL) ☒

Spillway (SS) ☒

Top of Dam Overflow (ST) ☒

If the Discharge Options are changed, it is necessary to recreate the Draft HEC-1 Network to add or remove relevant data.

Option Details

Low-Level Outlet (SL)

Centerline Elevation	96.0
Cross-Section Area	4.00
Discharge Coefficient	0.70
Orifice Equation Exponent	0.50

Spillway Characteristics (SS)

Spillway Crest Elevation	98.0
Spillway Length	20.00
Discharge Coefficient	3.00
Weir Equation Exponent	1.50

Top of Dam Overflow (ST)

Elevation Top of Dam	100.0
Length Top of Dam	50.00
Discharge Coefficient	3.00
Weir Equation Exponent	1.50

The data is for Lesson #1 - from Hydrology and Storm Drainage Hydraulics Training Book

Info ReSort Copy Print... Delete Add MB Graph OK

- (j) Click the **Storage/Elevation** tab to enter the rating data shown below:

HEC-1 Storage Facilities - MB: 01

List Details Storage/Elevation/Discharge

Storage Facilities Rating Data

	Storage (ac-ft)	Elevation (ft)		Storage (ac-ft)	Elevation (ft)
1.	0.00	95.0	11.		
2.	1.00	96.00	12.		
3.	2.00	97.00	13.		
4.	3.00	98.00	14.		
5.	5.00	99.00	15.		
6.	8.00	100.00	16.		
7.	25.00	105.00	17.		
8.			18.		
9.			19.		
10.			20.		

Storage ID: **ST0010** Use Surface Area ☐

Info ReSort Copy Print... Delete Add MB Graph OK

- (k) Click the **Save** button to save the entered data.

- (l) Click the **OK** button to close the **HEC-1 STORAGE FACILITIES** form.

(H) Step 8 - Establish Routing Data

To enter Routing Data do the following:

- (a) From the menu bar of the main application window, click **Hydrology** → **HEC-1** → **Routing** to open the **HEC-1 ROUTING DATA** window.

- (b) Click **Add** to add a record and enter the following data:

- **Route ID:** *010010*
- **Type:** *Kinematic Wave*
- **Shape:** *CHANNEL*
- **Length (ft):** *800.00*
- **Slope (ft/ft):** *0.0100*
- **Manning's N:** *0.040*
- **Width (ft):** *100.00*
- **Side Slope (h:v):** *1.00*
- **Channel Loss checkbox:** *Uncheck*

Look for:

ID	Type
010010	Kinematic Wave

Route

Major Basin ID:

Route ID:

Type:

☐ Channel Loss

Kinematic Wave

Shape: [Custom](#)

Length (ft):

Slope (ft/ft):

Man'g N:

Width (ft):

Side Slope (h/v):

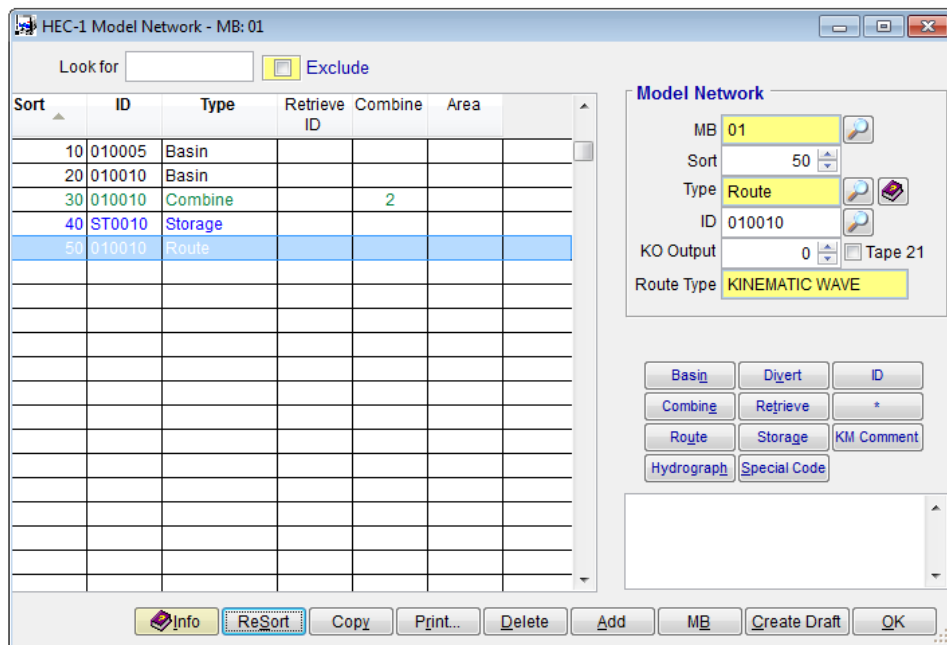
- (c) Click the **Save** button to save the entered data.
- (d) Click the **OK** button to close the **HEC-1 ROUTING DATA** form.

(I) Step 9 - Develop Hydrology Network

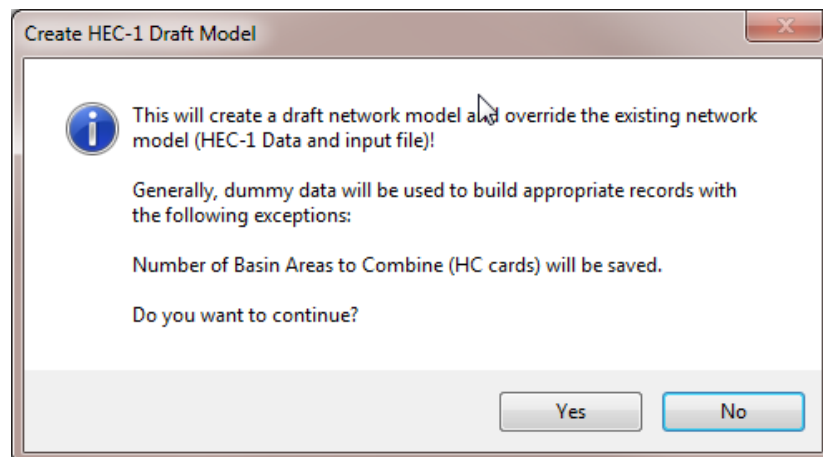
To develop the Model Network, do the following steps:

- (a) From the menu bar of the main application window, click **Hydrology → HEC-1 → Network** to open the **HEC-1 MODEL NETWORK** form.
- (b) On the **HEC-1 MODEL NETWORK** window, click **Add** to add a record and select "*Basin*" from the **SELECT TYPE** window.
- (c) Click **OK** to close the **SELECT TYPE** window.
- (d) Click the "Magnifying Glass" (or Selector) button to the right of **ID** textbox and select **Sub Basin ID** "010005"
- (e) Click **OK** to close the **SELECT ID** window.
- (f) Click **Save** to save the entered data.
- (g) Click the **Basin** button to add another Sub Basin and select "010010" from the **SELECT ID** window.
- (h) Click **OK** to close the **SELECT ID** window.
- (i) Click the **Combine** button to combine the preceding two (2) Sub Basins.
- (j) Click **Storage** to add a Storage Facility and select "ST0010" from the **SELECT ID** window.
- (k) Click **OK** to close the **SELECT ID** window.
- (l) Click **Route** to add a Route and select "010010" from the **SELECT ID** window.
- (m) Click **OK** to close the **SELECT ID** window.
- (n) Click **ReSort** to provide more room for inclusive records if needed.

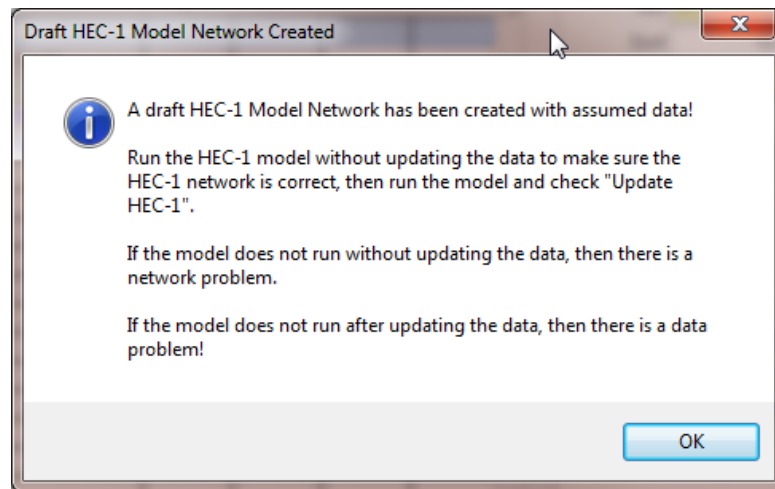
Before creating a draft model, the **HEC-1 MODEL NETWORK** form should look like the following figure.



(o) Click **Create Draft** to create the draft **HEC-1** model.

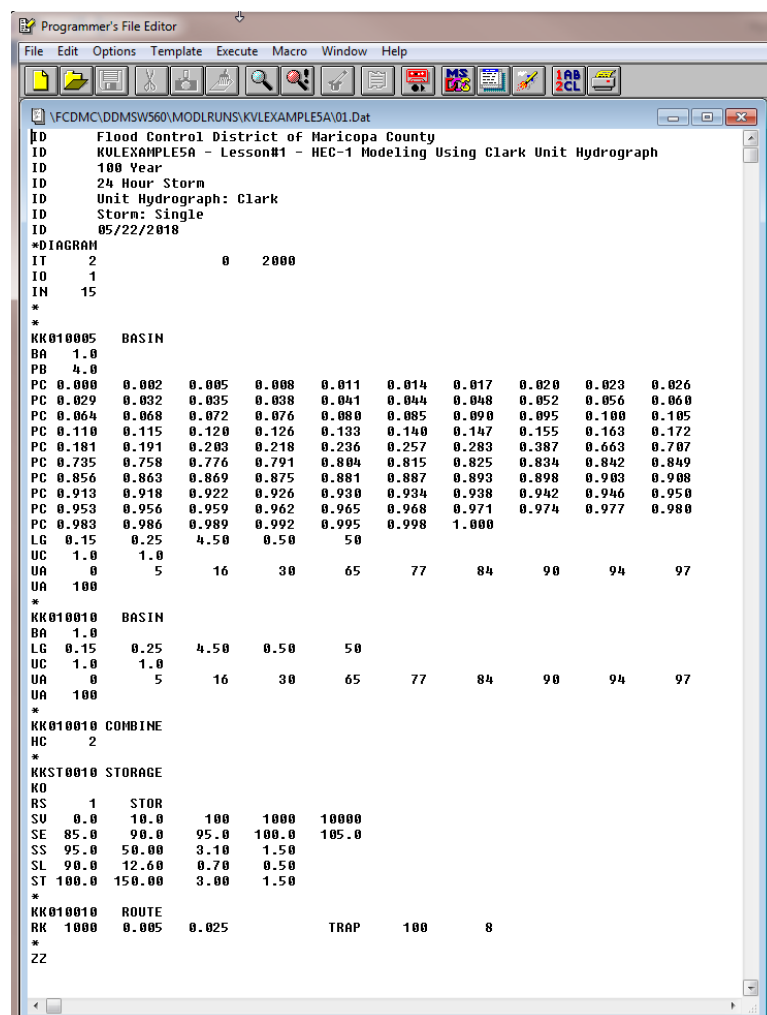


(p) Click **Yes** to continue and to close the **CREATE HEC-1 DRAFT MODEL** dialog box.



(q) Click **OK** to continue and to close the **DRAFT HEC-1 MODEL NETWORK CREATED** dialog box.

Subsequent to closing of the **DRAFT HEC-1 MODEL NETWORK CREATED** dialog box, the **PROGRAMMER'S FILE EDITOR** form opens showing the draft HEC-1 model.



- (r) Close the **PROGRAMMER'S FILE EDITOR**.
- (s) Close the **HEC-1 MODEL NETWORK** form by clicking the **OK** button.

(J) Step 10 - Run HEC-1 Model

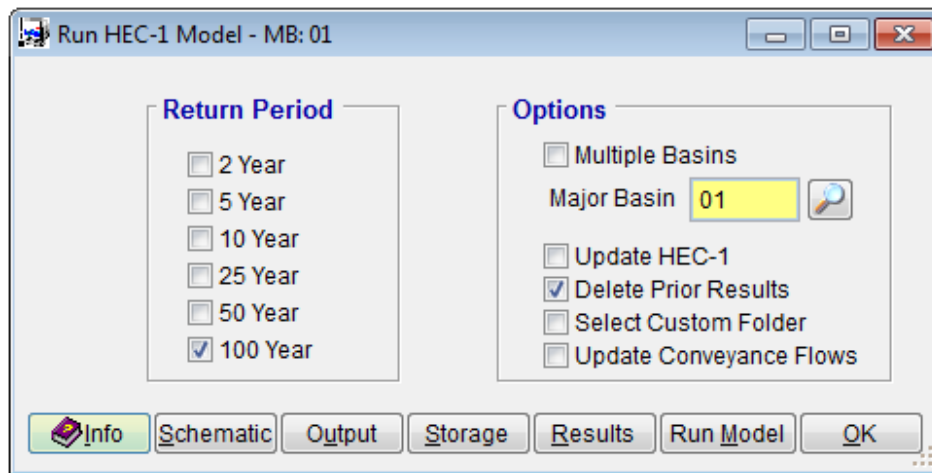
To run the **HEC-1** model, do the following steps:

- (a) From the menu bar of the main application window, click **Hydrology** → **HEC-1** → **Model** to open the **RUN HEC-1 MODEL** form.

(J.1) Run the Draft Model

Initially, the model will be run with “dummy” data developed for the draft input file. If the model runs without errors, then it can be assumed that the network has been developed correctly.

- (a) On the **RUN HEC-1 MODEL** form, uncheck all return periods except for the **100 year**.



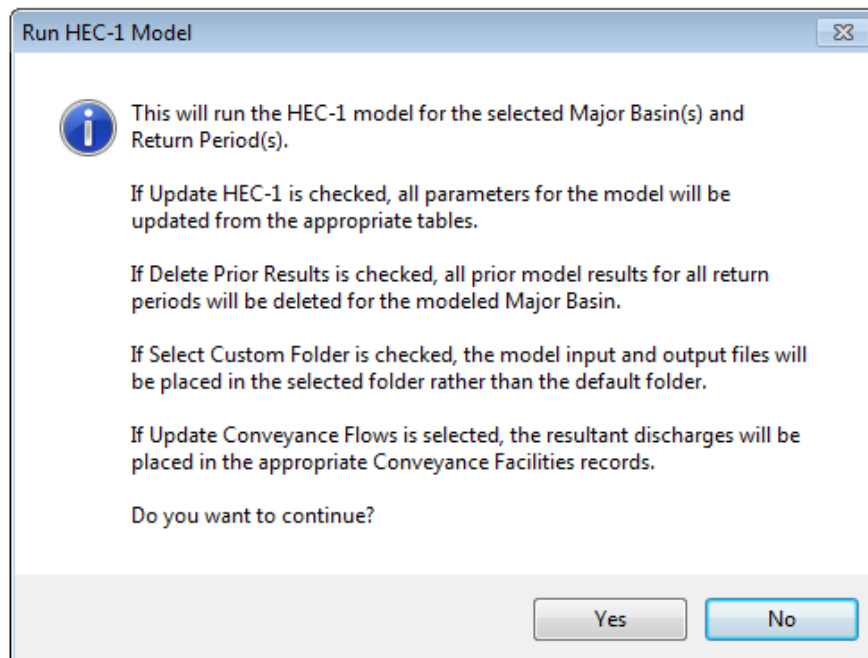
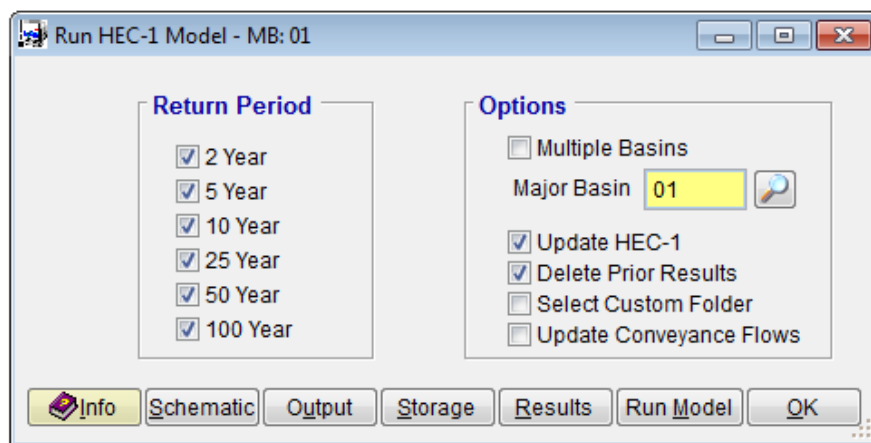
- (b) Uncheck **Update HEC-1**
- (c) Check **Delete Prior Results**
- (d) Uncheck **Select Custom Folder**
- (e) Uncheck **Update Conveyance Flows**
- (f) Click the **Save** button to save the entered data
- (g) Click **Run Model** to run the draft model

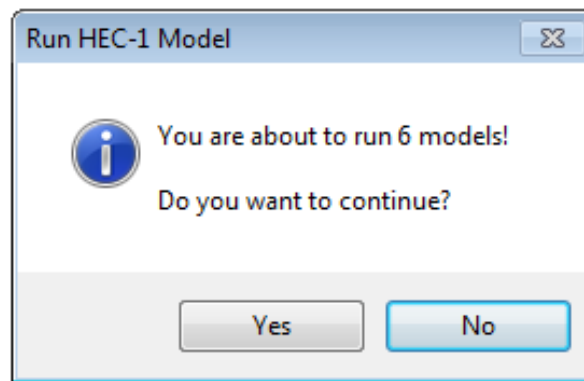
(h) Click **Yes** when the **RUN HEC-1 MODEL** dialog box appears.

(J.2) Run the Model

If no errors were generated when running the Draft Model, then do the following steps:

- (a) Check all return periods
- (b) Check **Update HEC-1**
- (c) Click **Save** button to save the entered data
- (d) Click **Run Model** to run the models





(e) Click **Yes** to both messages to run the models.

(f) Click **OK** to close the **RUN HEC-1 MODEL** form after the successful execution of the HEC-1 models.

(K) Step 11 - Review Model Results

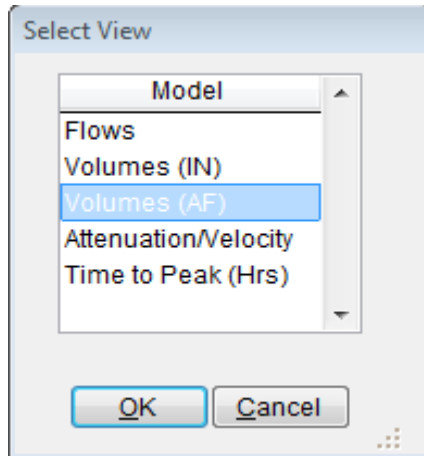
To view the **HEC-1** model flow and volume results do the following:

(a) From the menu bar of the main application window, click **Hydrology** → **HEC-1** → **Flow Summary** to open the **HEC-1 FLOW SUMMARY** form.

 A screenshot of the "HEC-1 Flow Summary - FLOWS - MB: 01" window. It features a search bar at the top labeled "Look for". Below it is a table with columns: ID, Sort, Type, Area, 2 Yr, 5 Yr, 10 Yr, 25 Yr, 50 Yr, and 100 Yr. The table contains four rows of data, each with a different background color (blue, light blue, green, and yellow). At the bottom of the window, there are buttons for Info, Export, Print..., View, MB, and OK.

ID	Sort	Type	Area	2 Yr	5 Yr	10 Yr	25 Yr	50 Yr	100 Yr
010005	10	Hydrograph	0.0			1	1	22	27
010010	20	Hydrograph	0.04	11	18	29	44	56	69
010010	30	Combined	0.05	17	26	40	61	78	95
ST0010	40	Routed	0.05	6	11	17	22	26	30
010010	50	Routed	0.05	6	11	17	22	26	30

(b) To view model volume results, click the **View** button on the **HEC-1 FLOW SUMMARY – FLOWS** form. On the **MODEL VIEW** dialog box, click the “Magnifying Glass” button to the right of **View** to open the **SELECT VIEW** window. Select “*Volumes (AF)*” from the list.



HEC-1 Flow Summary - VOLUMES (AF) - MB: 01

Look for

ID	Sort	Type	Area	2 Yr	5 Yr	10 Yr	25 Yr	50 Yr	100 Yr
010005	10	Hydrograph	0.02	0.75	0.95	1.16	1.52	1.80	2.06
010010	20	Hydrograph	0.04	1.03	1.41	1.83	2.41	2.87	3.35
010010	30	Combined	0.05	1.76	2.36	3.01	3.93	4.67	5.43
ST0010	40	Routed	0.05	0.75	1.34	1.99	2.91	3.65	4.41
010010	50	Routed	0.05	0.76	1.34	1.99	2.91	3.65	4.42

Info Export Print... View MB OK

- (e) After examining the tabulated results, click **OK** to close the **HEC-1 FLOW SUMMARY– VOLUMES (AF)** form.
- (f) To view the Model Storage results, click **Hydrology → HEC-1 → Storage Summary** to open the **HEC-1 STORAGE SUMMARY** form.
- (g) On the **HEC-1 STORAGE SUMMARY** form, click the **Details** tab to view the storage volume and stage results.

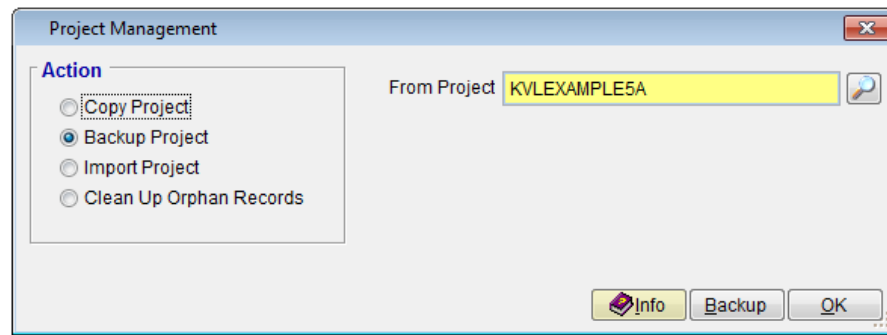
Year	Volume (ac-ft)	Stage (ft)	Q (cfs)
2	1.00	96.06	6
5	1.00	96.26	11
10	2.00	96.55	17
25	2.00	97.00	22
50	2.00	97.37	26
100	3.00	97.73	30


- (h) After examining the results, click **OK** to close the **HEC-1 STORAGE SUMMARY** window.

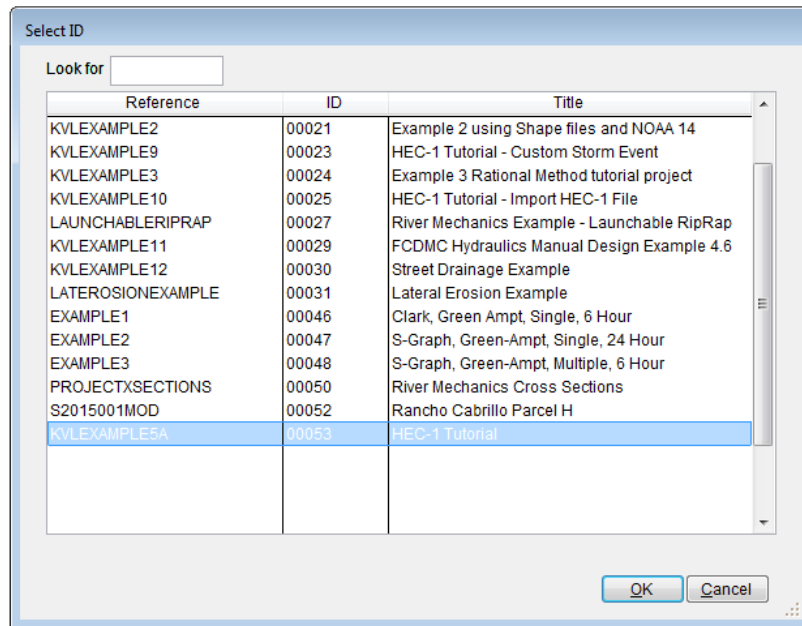
(L) Step 12 - Backup Project

To create a backup file for the project, do the following:

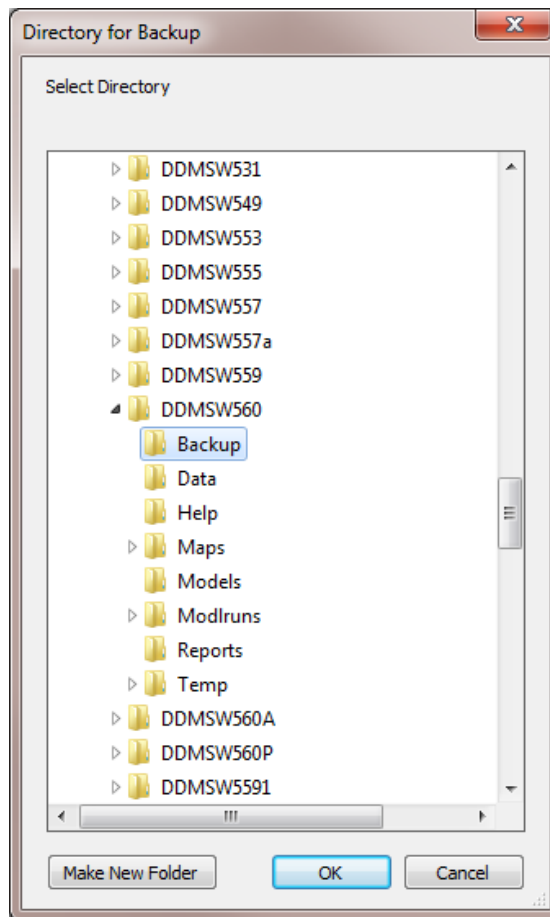
- (a) From the menu bar of the main application window, click **File → Project Management** to open the **PROJECT MANAGEMENT** dialog box.
- (b) On the **PROJECT MANAGEMENT** dialog box, select the **Backup Project** radio button.



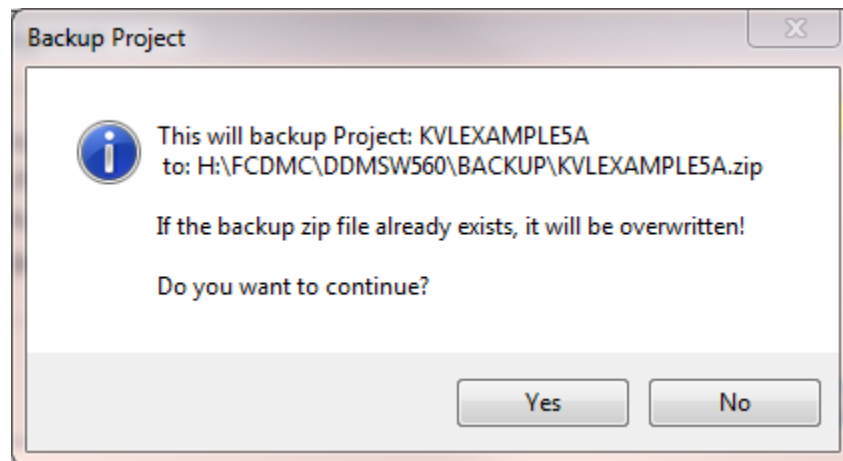
- (c) Click the “Magnifying Glass”  button to the right of **From Project** to open the **SELECT ID** form.



- (d) Select “KVLEXAMPLE5A” (if not selected already) and click the **OK** button to close the **SELECT ID** form.
- (e) Click **Save** on the **PROJECT MANAGEMENT** dialog box to save the data.
- (f) Click the **Backup** button.
- (g) Select a folder where the backup file will be saved (defaults to **Backup** sub directory)

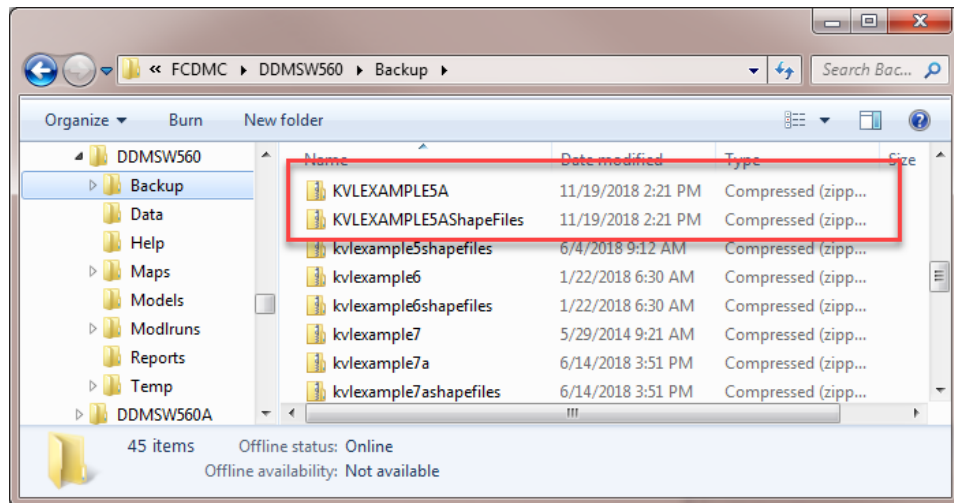


(h) Click **OK**. On the **BACKUP PROJECT** dialog box, click **Yes** to continue.



- (i) After the backup files had been successfully created, click **OK** to close the **PROJECT MANAGEMENT** dialog box.
- (j) To check the backup files that were just created, navigate to the **Backup** folder. Notice the two new zip files in the list as follows:

- (1) KVLEXAMPLE5A.zip
- (2) KVLEXAMPLE5AShapeFiles.zip



This concludes this tutorial.

1.2 RATIONAL METHOD

1.2.1 Problem Statement

Estimate the 10-year design discharge for a storm drainage system using **GIS** data for Sub Basins, Land Use and Time of Concentration (Tc) with the following given conditions:

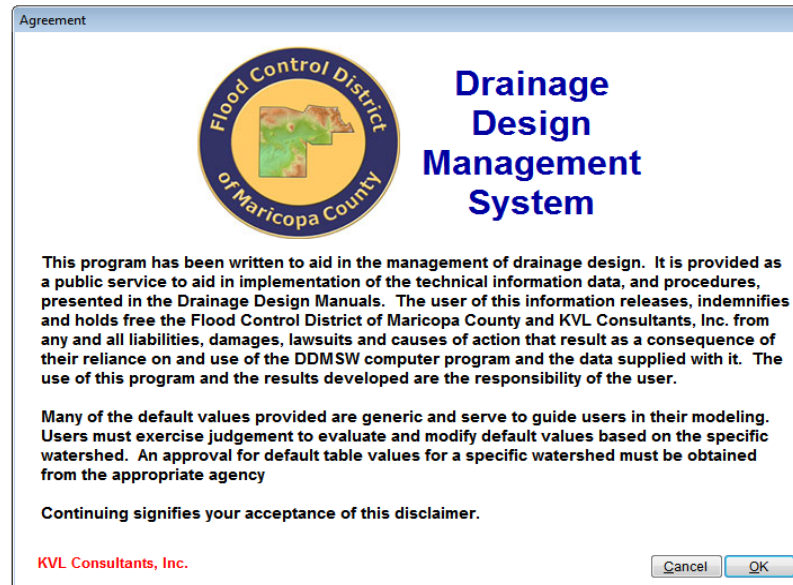
- ❖ Rational Method Model
- ❖ FCDMC Land Use
- ❖ NOAA14 Rainfall
- ❖ MCDOT Roads
- ❖ Minimum Tc
- ❖ Maximum Tc

1.2.2 Step-by-Step Procedures

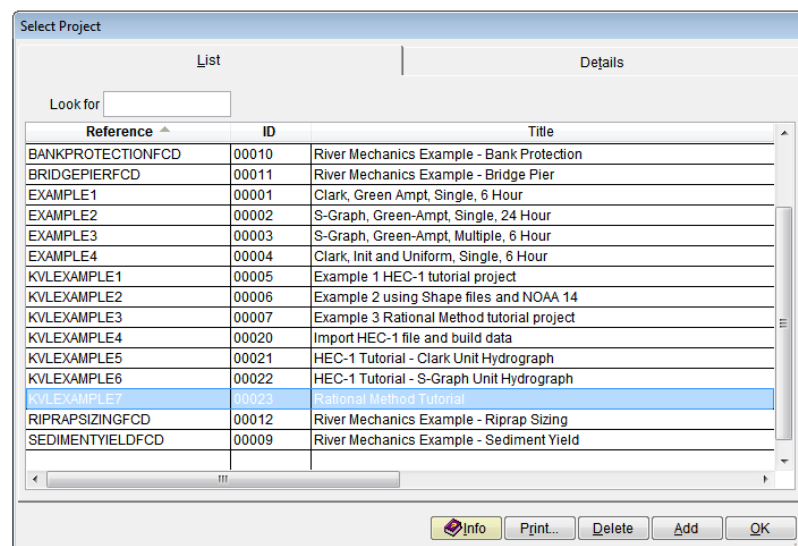
- Step 1: Establish a New Project and Default Set-up.
- Step 2: Prepare Maps
- Step 3: Establish Rainfall Data from **GIS**
- Step 4: Establish Sub Basin and Land Use Data from **GIS**
- Step 5: Review Established Sub Basin and Land Use Data
- Step 6: Establish Conveyance Facility Data
- Step 7: Develop **RATIONAL METHOD** Network
- Step 8: Run **RATIONAL METHOD** Model
- Step 9: Review Model Results
- Step 10: Backup Project

(A) Step 1 - Establish a New Project and Defaults Set-Up

- (a) Click the **DDMSW** icon on the Desktop or Program menu to launch the **DDMSW**. Click **OK** to accept the software disclaimer as is shown in the following figure.



After the **DDMSW** is launched, the **SELECT PROJECT** window is automatically opened as is shown in the following figure.



- (b) Click the **Add** button on the **SELECT PROJECT** window to start a new project (Or **File** ➔ **New Project** ➔ **Add**).

- (c) On the **NEW PROJECT OPTIONS** dialog box, select **Hydrology and Hydraulics** checkbox and select the **Standard** radio button. Click the **OK** button to close the dialog box.
- (d) On the **SELECT PROJECT** form, type “KVLEXAMPLE7A” into the **Reference** textbox. This is the name of this newly created project. The users can choose the name as long as it does not exist in the DDMSW database.
- (e) Type into the **Title** textbox a brief descriptive title of this project. **(Optional)**
- (f) Type into the **Location** textbox the location of this project. **(Optional)**
- (g) Type into the **Agency** textbox the agency or company name. **(Optional)**
- (h) Type a detailed description of this project into the textbox on the bottom left side of the window. **(Optional)**
- (i) Under **Project Defaults** frame, change the default Model from “HEC1” to “Rational” by clicking on the magnifying glass.
- (j) Click the **Save** button to save the entered data.
- (k) Click the **OK** button on the **SELECT PROJECT** window to close it. The screen shot below shows the completed form after data entries made.

The screenshot shows the 'Select Project' dialog box with the following details:

- Project Reference:**
 - Project ID: 00065
 - Reference: KVLEXAMPLE7A
 - Title: Rational Method Tutorial
 - Location: Maricopa County
 - Agency: Flood Control District of Maricopa County
 - ☒ Hydrology and Hydraulics Only
- Project Defaults:**
 - Model: Rational
 - Land Use: FCDMC
 - Rainfall: NOAA14
 - Roads: MCDOT
 - Inlets: MAG
- Min/Max Tc (minutes):**
 - Minimum Tc: 10
 - Maximum Tc: 90
- Description:** This project is set-up to provide a step-by-step instruction on how to use DDMSW using Rational Method.
- Modification Date:** 11/19/2018
- Buttons:** Info, Print..., Delete, Add, OK

- (l) Click **OK** button on the pop-up message box.

Note: The **Project ID** “00051” in the above figure is the unique read-only project identifier in the project database, which is automatically generated by the program when a new project is created. When users create the new project, the **Project ID** generated will not be the same as the **Project ID** shown in the above figure.

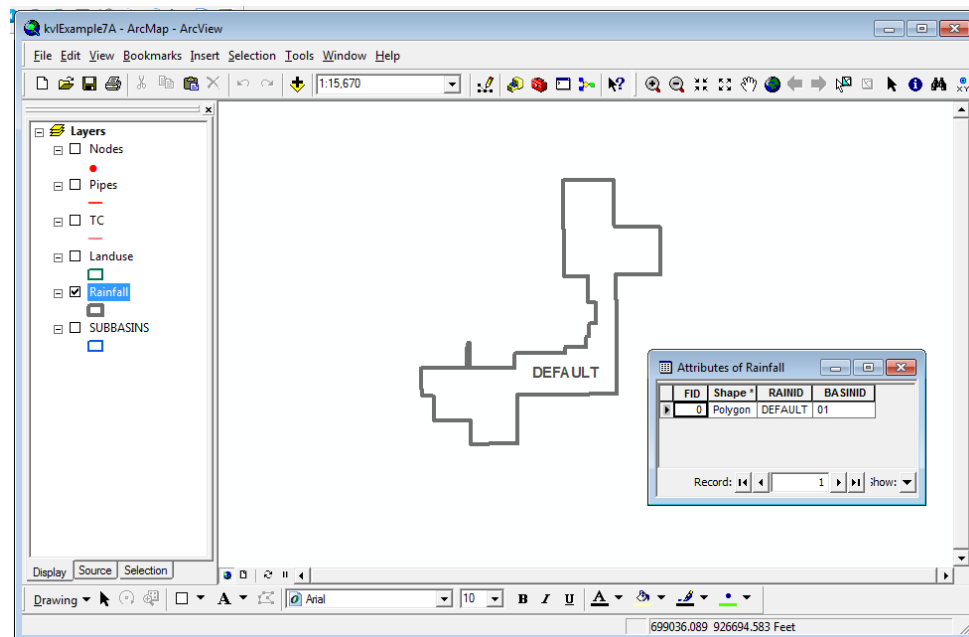
(B) Step 2 - Prepare ESRI Shape Files

This step is only for information purposes. There is no action required for the tutorial user in this step. Several ESRI shape files must be prepared. They are *rainfall*, *sub basin*, *land use* and *Tc*. As part of the shape files, the table structures must include specific fields. For the purposes of this tutorial, all these shape files have already been prepared. This tutorial does not cover the creation of the shape files. For tutorials on how to create ESRI shape files, please refer to “**HOW TO PREPARE ESRI SHAPE FILES FOR DDMSW**” document that can be downloaded from the District website (<https://www.maricopa.gov/264/How-to-Prepare-ESRI-Shape-Files>).

This section describes the general requirement for the required shape file tables. Assigning file names to the shape files to be used are not critical. For the purpose of this tutorial, however, map files are named based on the data they represent. It is important, however, that field names inside the tables must be fixed as provided in the following sections.

(B.1) Rainfall

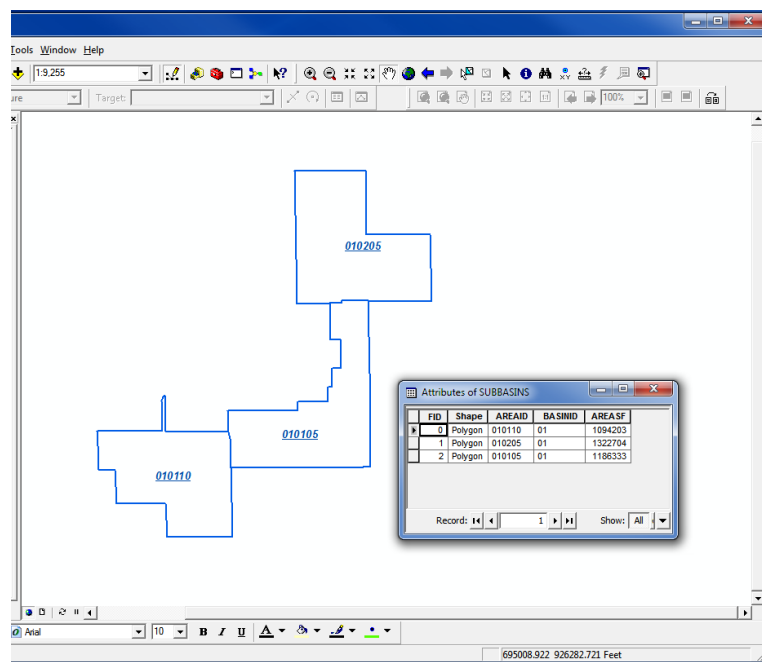
The Rainfall map (*Rainfall.shp*) will contain a single polygon with two attribute fields namely, “**RAINID**” and “**BASINID**”. **RAINID** is a Character 8 data type, indicating a Text or String data field that is 8 characters long. **BASINID**, on the other hand, is a Character 2 data type indicating a Text or String data field of 2 characters long. The Rainfall map can be created after the Sub Basins map (*Subbasins.shp*) has been prepared and is the combined polygon area of all the modeled Sub Basins.



(B.2) Sub Basins

The Sub Basins map (*Subbasins.shp*) will contain one polygon for each Sub Basin in the project. The required fields include:

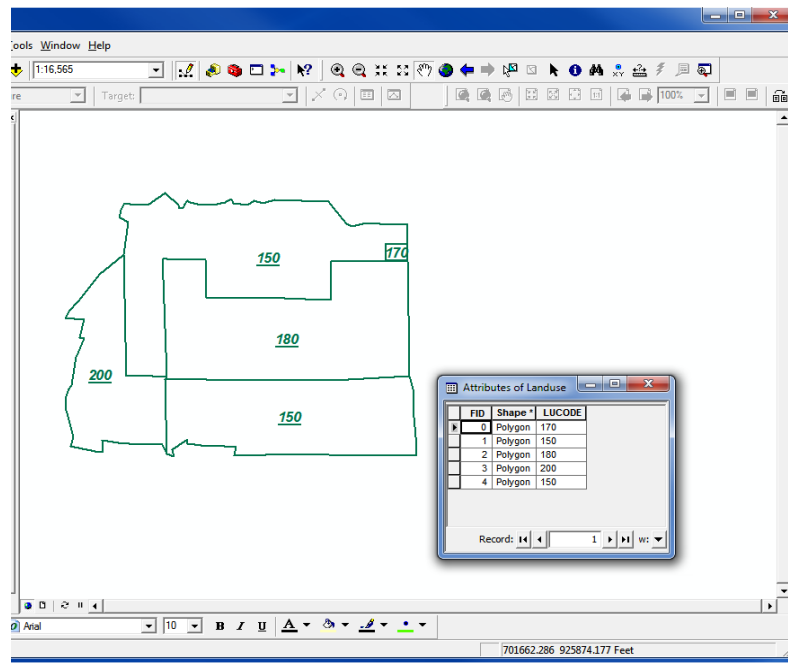
- ❖ **AREAID** Character 6 Enter unique **SubBasin ID**
- ❖ **BASINID** Character 2 Enter **Major Basin ID**
- ❖ **AREASF** Numeric 12.0 Data entered into this field will be overwritten internally by DDMSW. This field contains the Sub Basin area in square feet. The data for this field is calculated automatically when the **Update** button is clicked in the **UPDATE HYDROLOGY FROM GIS** form in DDMSW.



(B.3) Land Use

The Land Use map (*Landuse.shp*) will contain polygons for Land Use data. There can be more than one polygon with the same **Land Use ID**. It is vitally necessary that the Land Use coverage extends beyond the extent of all Sub Basins. The only required attribute field for the Land Use map is:

- ❖ **LUCODE** Character 15 **LUCODE** values should be consistent with the values in the DDMSW Land Use defaults table.

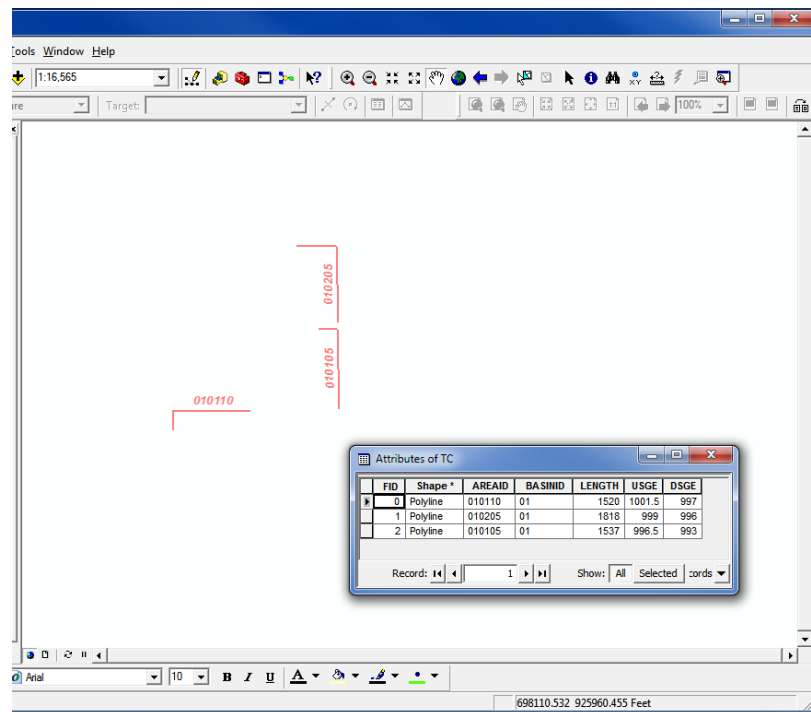


(B.4) Tc

The Time of Concentration map (*Tc.shp*) will contain polylines for Tc data. There needs to be one Tc polyline for each Sub Basin in the project and each polyline must be completely contained within its respective Sub Basin. The required fields include:

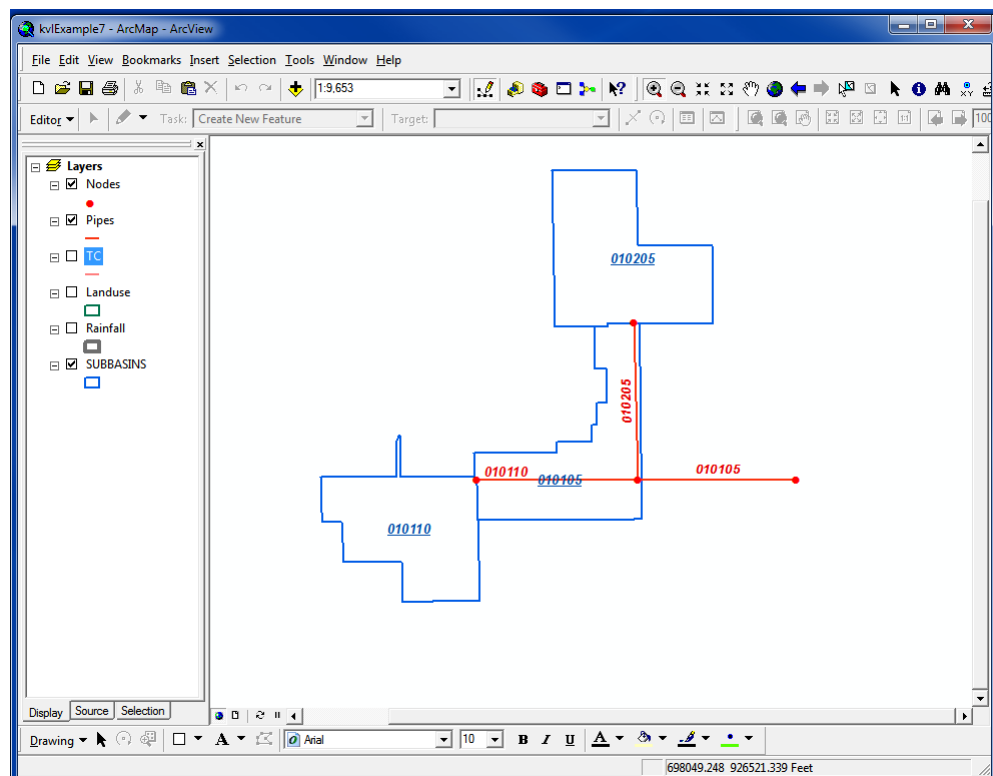
- ❖ **AREAID** Character 6 This is determined internally by DDMSW.
- ❖ **BASINID** Character 2 This is determined internally by DDMSW.
- ❖ **LENGTH** Numeric 12.0 The value of this attribute field is calculated internally by DDMSW
- ❖ **USGE** Numeric 9.2 Enter the upstream ground elevation in feet.
- ❖ **DSGE** Numeric 9.2 Enter the downstream ground elevation in feet.

The data for **AREAID**, **BASINID** and **LENGTH** are populated automatically when the **Update** button is clicked in the **UPDATE HYDROLOGY FROM GIS** form. Any data manually entered will be over-written.



(B.5) Layout

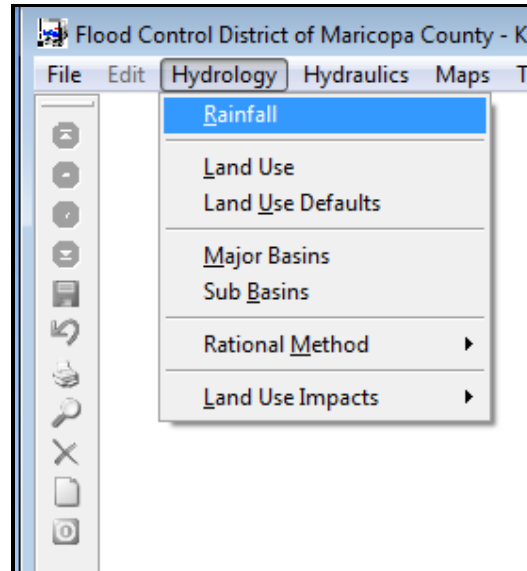
This map is for information only. It shows the layout of the Pipes (*Pipes.shp*) and Sub Basins (*Subbasins.shp*). Use this map as a guide when establishing the model network (which will be done later in this tutorial).




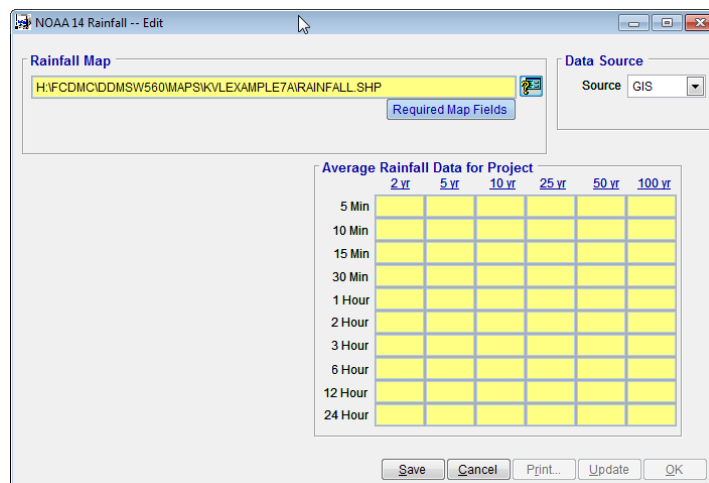
(C) Step 3 - Establish Rainfall Data from GIS

(C.1) Rainfall

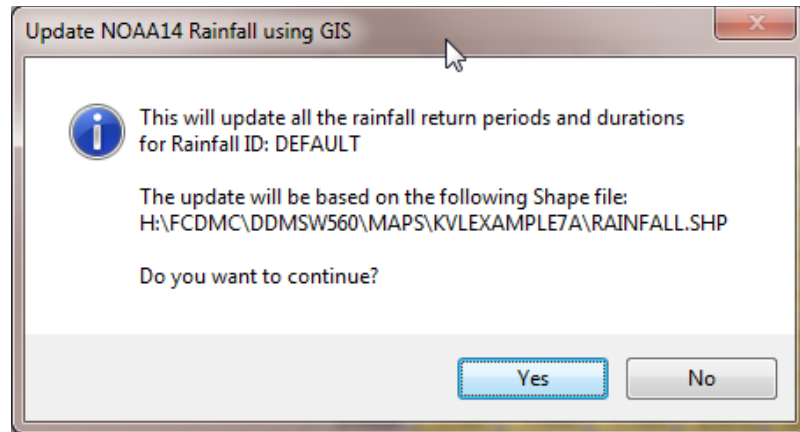
- (a) From the menu bar of the main application window, click **Hydrology** → **Rainfall** as shown in the following figure to open the **NOAA 14 RAINFALL** window.



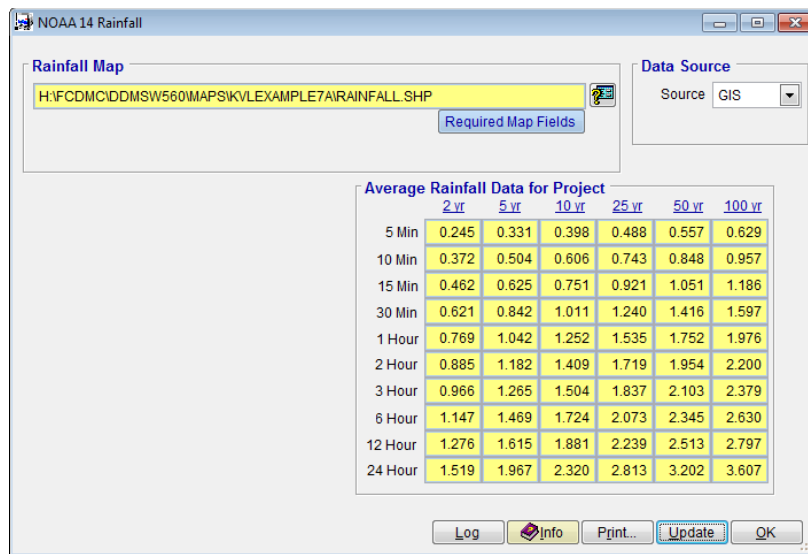
- (b) Ensure that the **Data Source** is set to "GIS". If the **Data Source** is not yet set to "GIS" then select "GIS" from the pull down menu
- (c) Click on the  button in the **Rainfall Map** textbox and select the Rainfall (*Rainfall.shp*) established earlier. It may be necessary to migrate to the folder where the shape file is in.
- (d) After selecting the rainfall map (*Rainfall.shp*), click the **Save** button.



- (e) Click **Update** to create the NOAA14 rainfall data from the **GIS** map. An **UPDATE NOAA14 RAINFALL USING GIS** dialog box will appear as shown below.



- (f) Click **Yes** to proceed.
- (g) When the update is finished, you will see the following results:

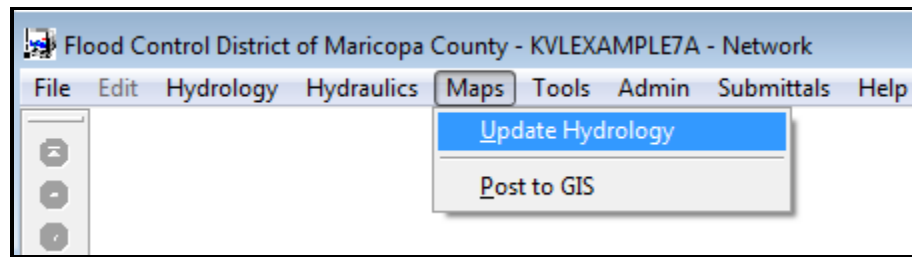





- (h) Click the **OK** button to close the **NOAA 14 RAINFALL** window.

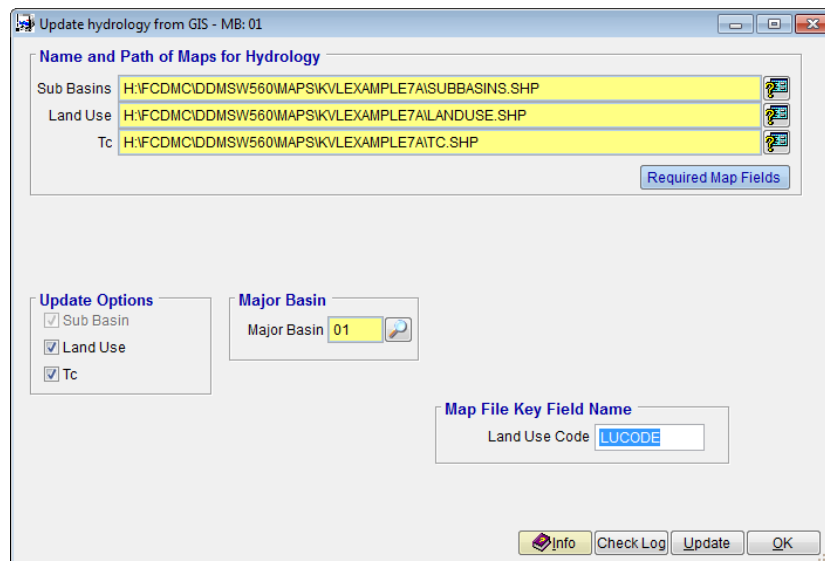
(D) Step 4 - Establish Sub Basin and Land Use Data from GIS

The project's Sub Basin and Land Use data can be populated in DDMSW from the maps created earlier.

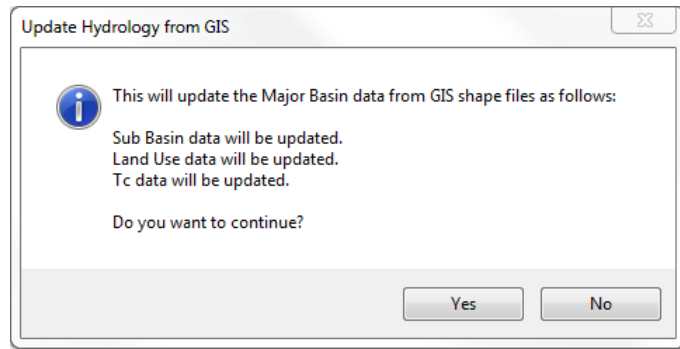
- (a) From the menu bar of the main application window, click **Maps** ➔ **Update Hydrology** as shown in the following figure to open the **UPDATE HYDROLOGY FROM GIS** window.



- (b) In the **Update Options** frame, check the **Land Use** and **Tc** check boxes.
- (c) In the **Map File Key Field Name** frame, enter “**LUCODE**” for **Land Use Code**.
- (d) Click the  button to the right of the **Sub Basins** and select the *SUBBASINS.shp* file. It may be necessary to migrate to the appropriate folder
- (e) Click the  to the right of the **Land Use** and select the *Landuse.shp* file
- (f) Click the  button to the right of the **Tc** and select the *TC.shp* file
- (g) Click **Save**. After saving the entries, the form should look like the figure below.



- (h) Click **Update**. An **UPDATE HYDROLOGY FROM GIS** dialog box will appear as shown below.



- (i) Click **Yes** to continue.
- (j) Click the **OK** button to close the **UPDATE HYDROLOGY FROM GIS** window.

(E) Step 5 - Review the Established Sub Basin and Land Use Data

The Sub Basin and Land Use data has been developed from the GIS maps. It is necessary to review the data to make sure everything looks sensical.

(E.1) Sub Basins

- (a) From the menu bar of the main application window, click **Hydrology** → **Sub Basins** to open the **SUB BASINS** form.
- (b) Click on the **Details** tab to view the data results summary of the three sub basins. The screen shot provided below shows the detailed data results summary for **Sub Basin "010105"**.

	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Q (cfs)	28.6	42.5	53.5	75.4	95.9	116.0
CA (ac)	19.88	19.88	19.88	21.78	23.69	24.78
Vol (ac-ft)	1.2780	1.6334	1.8889	2.4125	2.8921	3.3062
Custom Tc	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tc (min)	24.3	20.9	19.2	17.4	16.4	15.5
i (in/hr)	1.44	2.14	2.69	3.46	4.05	4.68

- (c) Click the **OK** button to close the **SUB BASINS** window.

(E.2) Land Use

- (a) From the menu bar of the main application window, click **Hydrology** → **Land Use** to open the **LAND USE** form.
- (b) Click on the **Details** tab to view the data

	Value	Default	Custom
2-Year C	0.68	0.68	<input type="checkbox"/>
5-Year C	0.68	0.68	<input type="checkbox"/>
10-Year C	0.68	0.68	<input type="checkbox"/>
25-Year C	0.75	0.75	<input type="checkbox"/>
50-Year C	0.80	0.80	<input type="checkbox"/>
100-Year C	0.84	0.84	<input type="checkbox"/>
Resistance Coefficient (Kb)	MIN	MIN	<input type="checkbox"/>

- (c) Click the **OK** button to close the **LAND USE** window.

(F) Step 6 - Establish Conveyance Facility Data

To enter Conveyance Facility data, which include the pipe network that conveys the system flows, do the following steps:

- (a) From the menu bar of the main application window, click **Hydraulics** → **Conveyance Facilities** to open the **CONVEYANCE FACILITIES** window.
- (b) Click the **Add** button to add a record and enter the following data:
 - **Facility ID:** Enter "010105"
 - **Line ID:** Enter "100"
 - **RP (yrs):** Select "10" from the **RP (yrs)** drop down by clicking on the magnifying glass.
 - **Model Road:** Uncheck the **Model Road** checkbox in the **Model Options** frame.
 - **First Pipe:** Uncheck the **First Pipe** checkbox in the **Model Options** frame.
 - **Outfall:** Check the **Outfall** checkbox in the **Model Options** frame. This is the outfall for the Main Pipe.
 - **D/S Pipe ID:** Leave the **D/S Pipe ID** textbox blank.

- **Ground U/S (ft):** Enter “993.00” in the **Elevations** frame
- **Ground D/S (ft):** Enter “988.00” in the **Elevations** frame
- **Invert U/S (ft):** Enter “988.00” in the **Elevations** frame
- **Invert D/s (ft):** Enter “984.00” in the **Elevations** frame
- **Section:** Select “*Pipe*” from the pull down in the **Section Type** frame
- **Length (ft):** Enter “1323.00” in the **Section Type** frame
- **Manning’s n:** Select “*Concrete Pipe for closed conduit*” in the **Section Type** frame by clicking on the magnifying glass.
- **Diameter (in):** Enter “54” in the **Section Type** frame
- **No. of Barrels:** Enter “1” in the **Section Type** frame.
- **No. of Manholes:** Enter “1” in the **Section Type** frame.

(c) Click the **Save** button to save the entered data. The completed data form for **Facility ID “010105”** should look like the following figure:

(d) Click **Add** to add a new record and enter the following data:

- **Facility ID:** Enter “010110”
- **Line ID:** Enter “100”
- **Model Road:** Check the **Model Road** check box in the **Model Options** frame
- **First Pipe:** Check the **First Pipe** check box in the **Model Options** frame
- **Outfall:** Uncheck the **Outfall** checkbox in the **Model Options** frame.

- **Ground U/S (ft):** Enter "997.00" in the **Elevations** frame
- **Ground D/S (ft):** Enter "993.00" in the **Elevations** frame
- **Invert U/S (ft):** Enter "990.00" in the **Elevations** frame
- **Invert D/S (ft):** Enter "988.00" in the **Elevations** frame
- **Section:** Select "Pipe" from the pull down in the **Section Type** frame
- **Length (ft):** Enter "1348.00" in the **Section Type** frame
- **Manning's n:** Select "Concrete Pipe for closed conduit" in the **Section Type** frame by clicking on the magnifying glass
- **Diameter (in):** Enter "48" in the **Section Type** frame
- **No. of Barrels:** Enter "1" in the **Section Type** frame
- **Road ID:** Select "MC-RMAR" in the **Section Type** frame by clicking on the magnifying glass
- **No. of Manholes:** Enter "1" in the **Section Type** frame

(e) Click the **Save** button to save the entered data. The completed data form for **Facility ID "010110"** should look like the following figure:

(f) Click **Add** to add another record and enter the following data:

- **Facility ID:** Enter "010205"
- **Model Road:** Check the **Model Road** in the **Model Options** frame
- **First Pipe:** Check the **First Pipe** in the **Model Options** frame
- **Outfall:** Check the **Outfall** checkbox in the **Model Options** frame. This is the outfall for the lateral pipe.

- **D/S Pipe ID:** Click the “Magnifying Glass” on the right of the **D/S Pipe ID** textbox and select “10105”.
- **Ground U/S (ft):** Enter “996.00” in the **Elevations** frame
- **Ground D/S (ft):** Enter “993.00” in the **Elevations** frame
- **Invert U/S (ft):** Enter “992.00” in the **Elevations** frame
- **Invert D/S (ft):** Enter “988.50” in the **Elevations** frame
- **Section:** Select “Pipe” from the pull down in the **Section Type** frame
- **Length (ft):** Enter “1318.00” in the **Section Type** frame
- **Manning’s n:** Select “Concrete Pipe for closed conduit” in the **Section Type** frame by clicking on the magnifying glass
- **Diameter (in):** Enter “42” in the **Section Type** frame
- **No. of Barrels:** Enter “1” in the **Section Type** frame
- **Road ID:** Select “MC-RMAR” in the **Section Type** frame by clicking on the magnifying glass
- **No. of Manholes:** Enter “1” in the **Section Type** frame

(g) Click the **Save** button to save the entered data. The completed data form for Facility ID “010205” should look like the following figure:

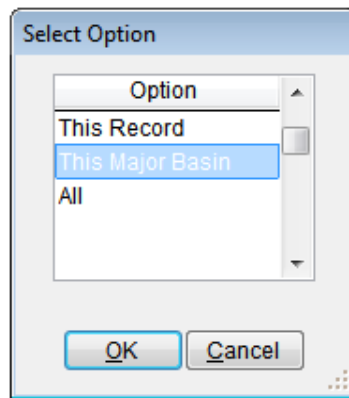
The screenshot shows the 'Conveyance Facilities - MB: 01' window with the 'Details' tab selected. The form is populated with the following data:

- ID Section:** MB ID: 01, Facility ID: 010205, Line ID: 100, Sort: 6.
- Section Type Section:** Section: Pipe, Length (ft): 1318.00, Manning's n: 0.013, Diameter (in): 42, No. of Barrels: 1, Road ID: MC-RMAR, No. of Manholes: 1.
- Model Options Section:** RP (yrs): 10, Q (cfs): [blank], Model Road: [checked], First Pipe: [checked], Outfall: [checked], D/S Pipe ID: 010105.
- Elevations Section:**

	U/S (ft)	D/S (ft)
Ground	996.00	993.00
Invert	992.00	988.50
- Calculations Section:** Capacity (cfs), Slope (ft/ft), Velocity (fps), and a table for Q (cfs), Road Depth (ft), and Upstream HGL (ft) for 2 Yr, 5 Yr, 10 Yr, 25 Yr, 50 Yr, and 100 Yr.

The bottom of the window contains buttons: Info, ReSort, Print..., Delete, Add, Graph, MB, Update, and OK.

(h) Click the **Update** button to perform hydraulic analysis for the conveyance facilities.



- (i) Select *"This Major Basin"* from the **SELECT OPTION** window.
- (j) Click **OK** to continue.
- (k) When the **UPDATE CONVEYANCE DATA** dialog box appears, click **Yes**.

The Normal Depth Capacity of the Conveyance facilities are calculated as shown below.

[illegible]

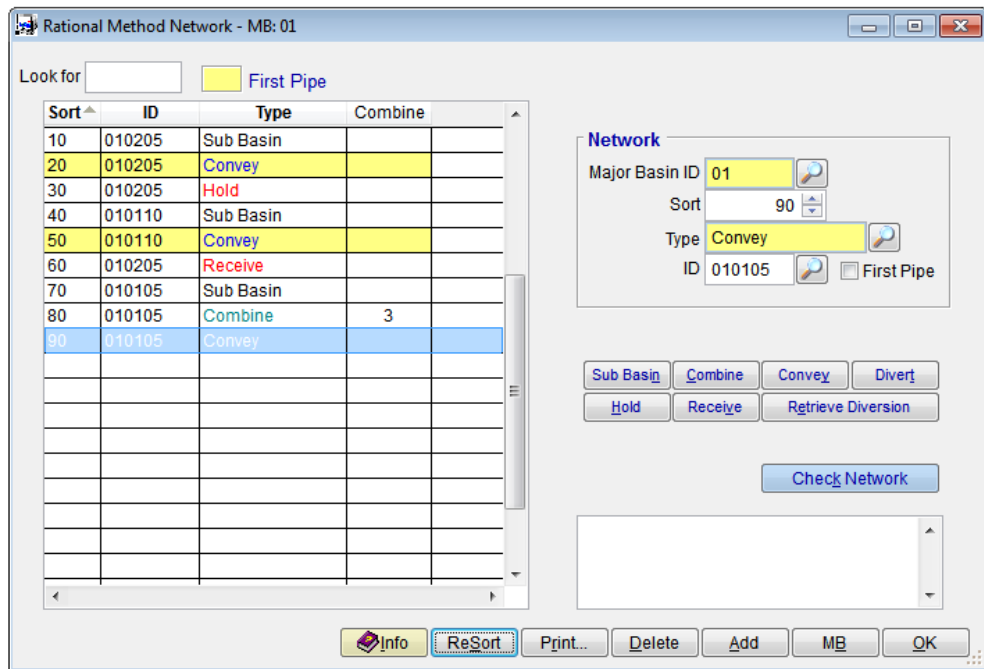
- (I) Click the **OK** button to close the **CONVEYANCE FACILITIES** window.

(G) Step 7 - Develop Rational Method Network

To enter Network data do the following:

- (a) From the menu bar of the main application window, click **Hydrology** ➔ **Rational Method** ➔ **Network** to open the **RATIONAL METHOD NETWORK** window.

- (b) Click **Add** to add a record and select **Sub Basin** from the **SELECT TYPE** window.
- (c) Click **OK** to close the **SELECT TYPE** window.
- (d) Click the button “Magnifying Glass” to the right of **ID** and select **Sub Basin ID** “010205”.
- (e) Click **OK** to close the **SUB BASIN ID** window.
- (f) Click **Save** to save the entered data.
- (g) Click **Convey** and select “010205” from the **CONVEYANCE ID** window.
- (h) Click **OK** to close the **CONVEYANCE ID** window.
- (i) Click **Hold** and select “010205” from the **HOLD ID** window.
- (j) Click **OK** to close the **HOLD ID** window.
- (k) Click **Sub Basin** and select “010110” from the **SUB BASIN ID** window.
- (l) Click **OK** to close the **SUB BASIN ID** window.
- (m) Click **Convey** and select “010110” from the **CONVEYANCE ID** window.
- (n) Click **OK** to close the **CONVEYANCE ID** window.
- (o) Click **Receive** and select “010205” from the **RECEIVE ID** window.
- (p) Click **OK** to close the **RECEIVE ID** window.
- (q) Click **Sub Basin** and select “010105” from the **SUB BASIN ID** window.
- (r) Click **OK** to close the **SUB BASIN ID** window.
- (s) Click the **Combine** button and change the **Combine** value from “2” to “3” in the **Network** frame.
- (t) Click **Save** to save the data.
- (u) Click **Convey** and select “010105” from the **CONVEYANCE ID** window.
- (v) Click **ReSort** to resort the data in increments of “10”.

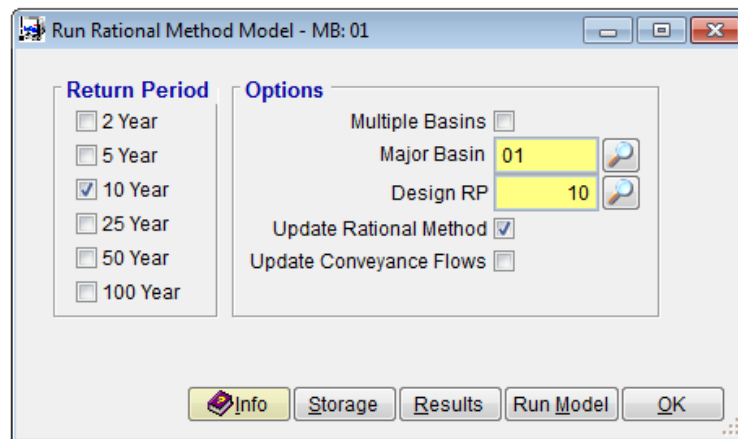


(w) Click the **OK** button to close the **RATIONAL METHOD NETWORK** window.

(H) Step 8 - Run Rational Method Model

To run a Draft Model of the Rational Method, do the following steps:

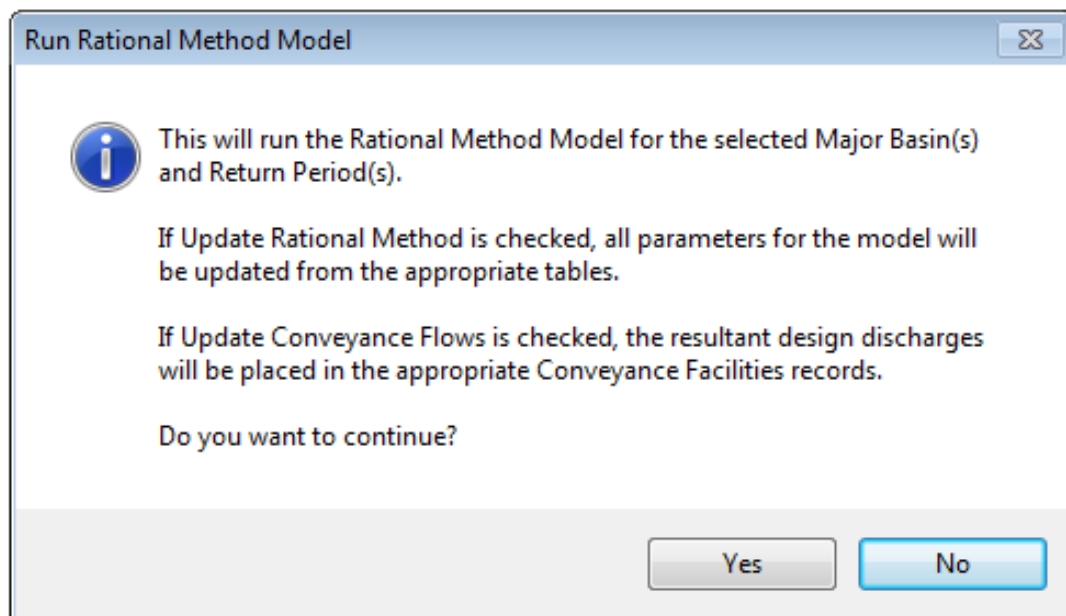
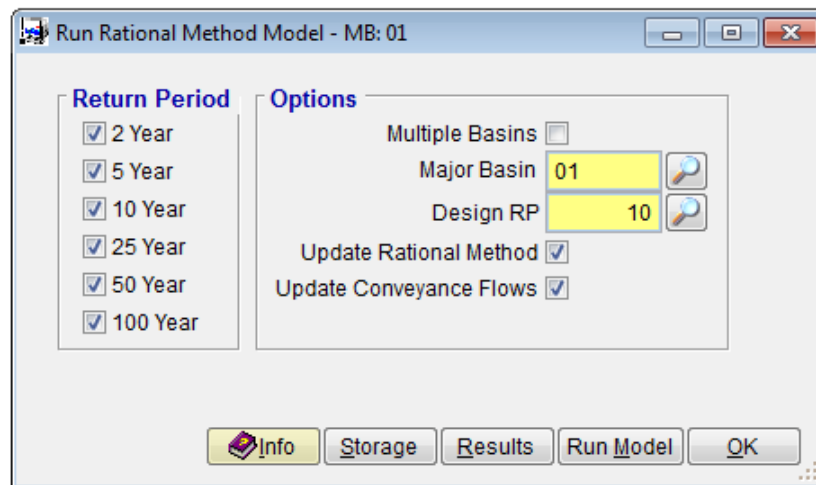
- From the menu bar of the main application window, click **Hydrology** → **Rational Method** → **Model** to open the **RUN RATIONAL METHOD MODEL** window.
- Using a **10-Year Return Period**, and with the **Update Rational Method** check box checked, run the model by clicking the **Run Model** button.



(H.1) Run Model

If there are no errors running the Draft Model, then do the following:

- (a) Check all return periods
- (b) Check the **Update Rational Method** check box
- (c) Check the **Update Conveyance Flows** check box
- (d) Click **Save**
- (e) Click **Run Model**.

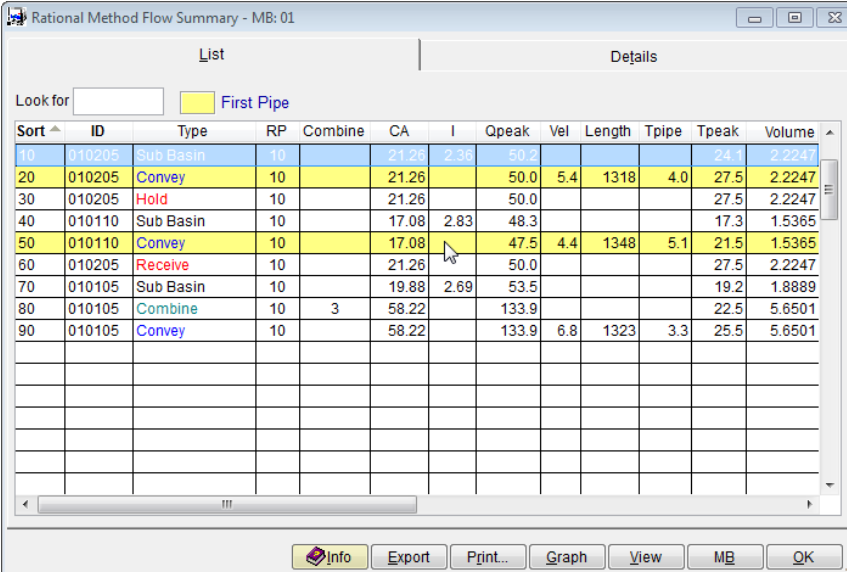


- (f) When the **RUN RATIONAL METHOD MODEL** dialog box appears, click **Yes** to continue.
- (g) Click the **OK** button to close the Window.

(I) Step 9 - Review Model Results

To view the model results from the Rational Method analysis, do the following steps:

- (a) From the menu bar of the main application window, click **Hydrology** ➔ **Rational Method** ➔ **Flow Summary** to open the **RATIONAL METHOD FLOW SUMMARY** window.

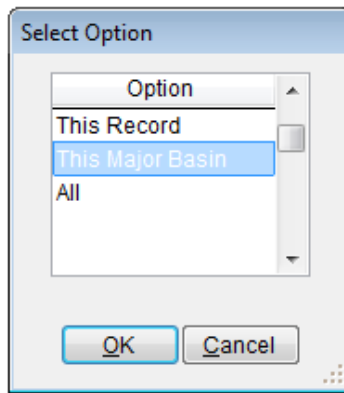


The screenshot shows the 'Rational Method Flow Summary - MB: 01' window. It has a 'List' tab selected. Below the tab is a 'Look for' field with a dropdown set to 'First Pipe'. A table displays flow data for various facilities. The table has columns: Sort, ID, Type, RP, Combine, CA, I, Qpeak, Vel, Length, Tpipe, Tpeak, and Volume. The data is as follows:

Sort	ID	Type	RP	Combine	CA	I	Qpeak	Vel	Length	Tpipe	Tpeak	Volume
10	010205	Sub Basin	10		21.35	2.35	50.0				24	2.2247
20	010205	Convey	10		21.26		50.0	5.4	1318	4.0	27.5	2.2247
30	010205	Hold	10		21.26		50.0				27.5	2.2247
40	010110	Sub Basin	10		17.08	2.83	48.3				17.3	1.5365
50	010110	Convey	10		17.08		47.5	4.4	1348	5.1	21.5	1.5365
60	010205	Receive	10		21.26		50.0				27.5	2.2247
70	010105	Sub Basin	10		19.88	2.69	53.5				19.2	1.8889
80	010105	Combine	10	3	58.22		133.9				22.5	5.6501
90	010105	Convey	10		58.22		133.9	6.8	1323	3.3	25.5	5.6501

At the bottom of the window are buttons: Info, Export, Print..., Graph, View, MB, and OK.

- (b) To view the model conveyance results, click **Hydraulics** ➔ **Conveyance Facilities** to open the **CONVEYANCE FACILITIES** window.
- (c) Migrate to **Facility ID "010105"** and click **Update**. This will update Road Depths of flow.



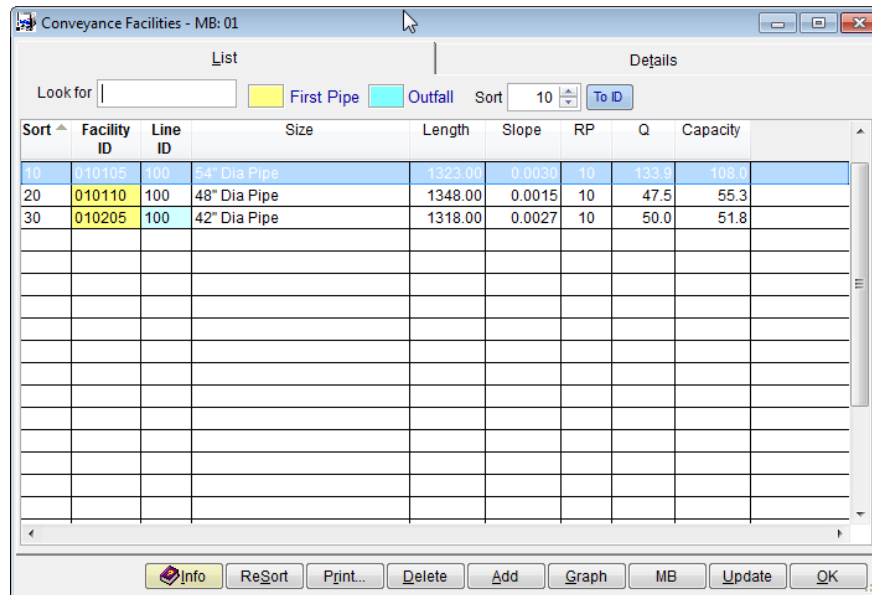
- (d) Select **This Major Basin**. The following form shows the results for **Facility ID "010205"**

The "Conveyance Facilities - MB: 01" form displays details for Facility ID 010205. The form is divided into several sections:

- ID**: MB ID (01), Facility ID (010205), Line ID (100), Sort (30).
- Model Options**: RP (yrs) (10), Q (cfs) (50.0), Custom (unchecked), Model Road (checked), First Pipe (checked), Outfall (checked), D/S Pipe ID (010105).
- Elevations**: U/S (ft) (996.00), D/S (ft) (993.00), Ground (996.00), Invert (992.00), D/S (ft) (988.50).
- Section Type**: Section (Pipe), Length (ft) (1318.00), Manning's n (0.013), Diameter (in) (42), No. of Barrels (1), Road ID (MC-RMAR), No. of Manholes (1).
- Calculations**: Capacity (cfs) (51.8), Slope (ft/ft) (0.0027), Velocity (fps) (5.4).
- Table**: A table showing Q (cfs), Road Depth (ft), and Upstream HGL (ft) for different return periods (2 Yr, 5 Yr, 10 Yr, 25 Yr, 50 Yr, 100 Yr).

	Q (cfs)	Road Depth (ft)	Upstream HGL (ft)
2 Yr	25.9		
5 Yr	38.9		
10 Yr	50.0		
25 Yr	72.6	0.89	
50 Yr	90.4	1.08	
100 Yr	110.3	1.20	

- (e) Further, the Conveyance Facilities (**Hydraulics → Conveyance Facilities**) summary results show the calculated Q for each pipe.

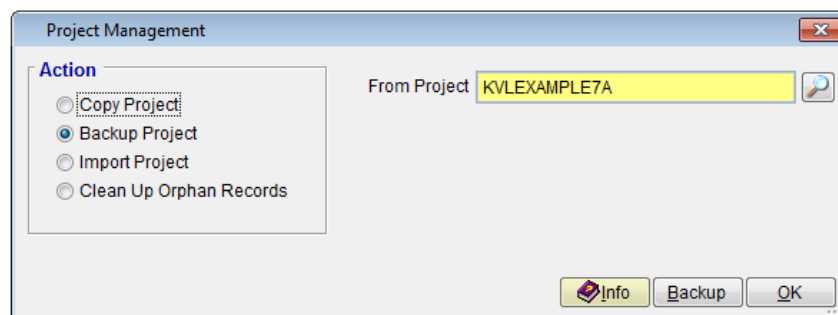


- (f) Click **OK** to close the **Conveyance Facilities** window.

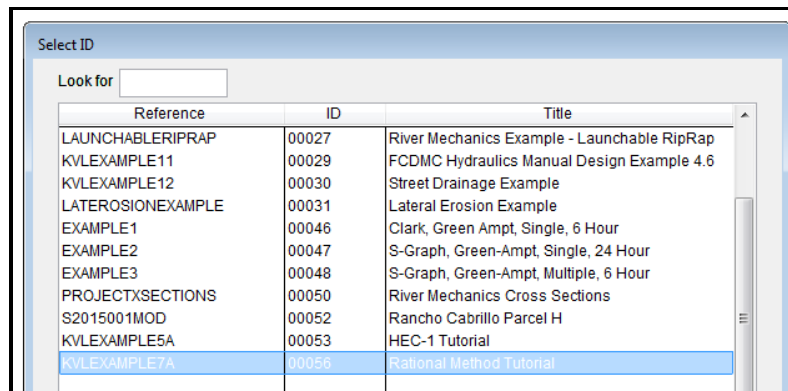
(J) Step 10 - Backup Project

To create backup files for the project, perform the following steps:

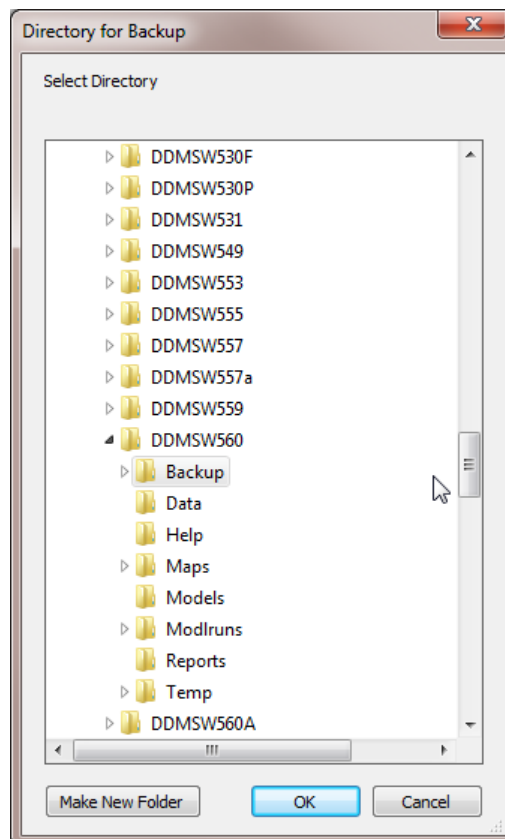
- (a) From the menu bar of the main application window, click **File** ➔ **Project Management** to open the **PROJECT MANAGEMENT** window.



- (b) Check **Backup Project**
- (c) Click the “Magnifying Glass” button to the right of **From Project** textbox to open the **SELECT ID** window.



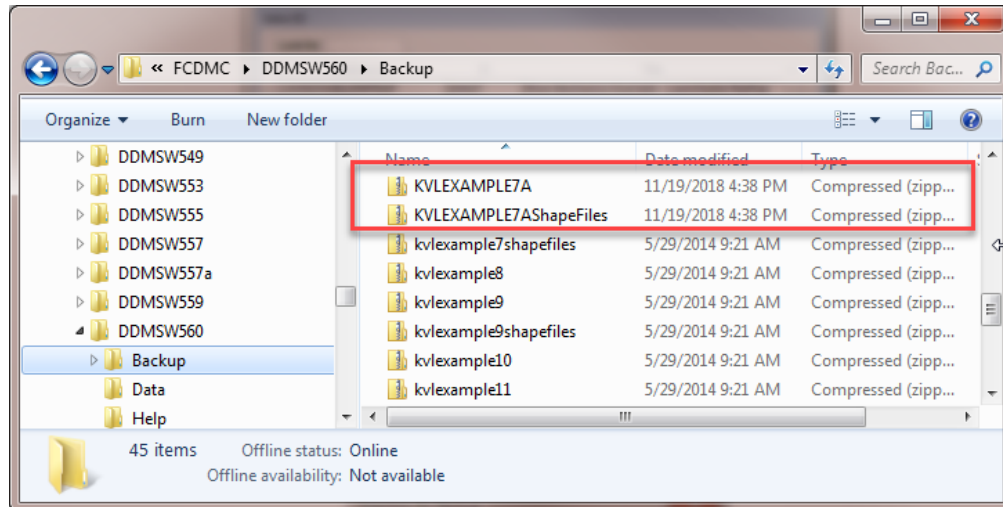
- (d) Select “KVLEXAMPLE7A” (if not already selected) and click the **OK** button to close the window.
- (e) Click **Save** to save the data on the **PROJECT MANAGEMENT** window.
- (f) Click **Backup**.
- (g) Select a folder where to save your backup file(s) (defaults to **Backup** sub directory)



- (h) Click **OK** to create backup file(s) for KVLEXAMPLE7A.
- (i) After the backup file(s) has been successfully created, click **OK** to close the **PROJECT MANAGEMENT** dialog box.

(j) To check the backup file(s) that were just created, navigate to the **Backup** folder. Notice the two new zip files in the list as follows:

- (1) KVLEXAMPLE7A.zip
- (2) KVLEXAMPLE7AShapeFiles.zip



This concludes this tutorial.

1.3 STORMPRO BACKWATER MODEL

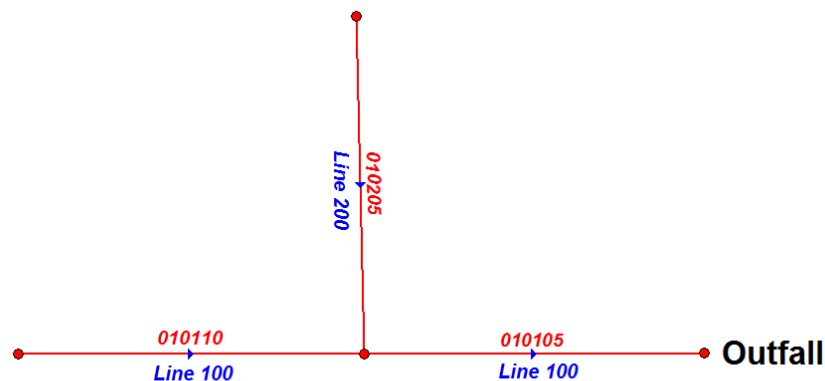
1.3.1 Problem Statement

This tutorial provides a working example for the use of the **STORMPRO** Backwater Model. For this example, before developing the backwater model, it is necessary to develop the hydrology using the Rational Method and enter the data for all conveyance facilities. The detailed procedure for the Rational Method and Conveyance Facilities for this tutorial is provided in **SECTION 1.2 - RATIONAL METHOD**. This tutorial starts after the **RATIONAL METHOD TUTORIAL** in **SECTION 1.2** is concluded.

1.3.2 Step-by-Step Procedures

The specific requirements for running **STORMPRO** using the pipe network shown below include:

1. Establishing a folder for the model runs
2. Modifying the Conveyance Facilities
3. Establishing the details for the Line IDs
4. Running the Model
5. Viewing Backwater Conveyance Results
6. Creating Backup for the Project



KvIExample7A Pipe Network

(A) Step 1 - Establish a Folder for Model Runs **(File → Project Paths)**

For this example, create a new folder in **\ModIRuns**:

Sort: For **STORMPRO** to run correctly, the **Facility ID**'s must be sorted in the order from Downstream to Upstream. Use the **Sort** field to force the correct order. **This is critical.**

Outfall: If a **Facility ID** is an Outfall, then check the **Outfall** checkbox. In this case, there are two outfalls. They are **Facility IDs** "010105" and "010205" for **Line IDs** "100" and "200", respectively.

D/S Pipe ID: If a **Facility ID** enters a Downstream Line, then enter the **D/S Pipe ID**. In the case of **Facility ID** "010205" for **Line ID** "200", enter **Pipe ID** "010105" (of **Line ID** "100") as the **D/S Pipe ID**.

Manholes: Enter the number of manholes in each **Facility ID**.

The screen capture of the form for **Facility ID** "010205" is shown below.

	Q (cfs)	Road Depth (ft)	Upstream HGL (ft)
2 Yr	25.9		
5 Yr	38.9		
10 Yr	50.0		
25 Yr	72.6	0.89	
50 Yr	90.4	1.08	
100 Yr	110.3	1.20	

(C) Step 3 - Establish the Line IDs (Hydraulics → StormPro Backwater → Lines)

When first going into this form, there will be no data and there will not be an **Add** button. The data for the Lines is established when clicking the **Update** button.

In this case, a warning will be given that there is no **Downstream ID** for **Line ID** "100" (because it is an **Outfall**). For this **Line ID** "100", check **Main Line** and click

Update. It is important to note that if the Conveyance Facilities are modified, then the **STORMPRO** Lines should be updated before running a **STORMPRO** Model.

[illegible]

For a **Main Line**, the Starting Hydraulic Grade Line for each return period can be entered. If left blank, the model uses the formula $(D_c + D)/2$, where D_c is the critical depth and D is the height of the **Facility ID**.

For Lines that are not a Main Line, a Starting Hydraulic Grade Line can be entered by checking the appropriate **Custom** for each return period. If left blank, the model establishes the value from the modeled Line that this Line enters.

(D) Step 4 - Run Model
(*Hydraulics → StormPro Backwater → Model*)


Run StormPro Model - MB: 01

Return Period

- ☒ 2 Year
- ☒ 5 Year
- ☒ 10 Year
- ☒ 25 Year
- ☒ 50 Year
- ☒ 100 Year

Options

All Lines ☒

Line ID 

Delete All Prior Results ☒

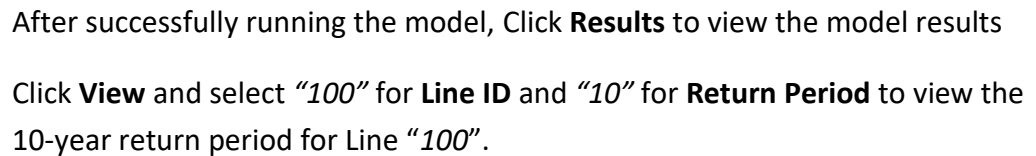
Error File

Output File

Input File

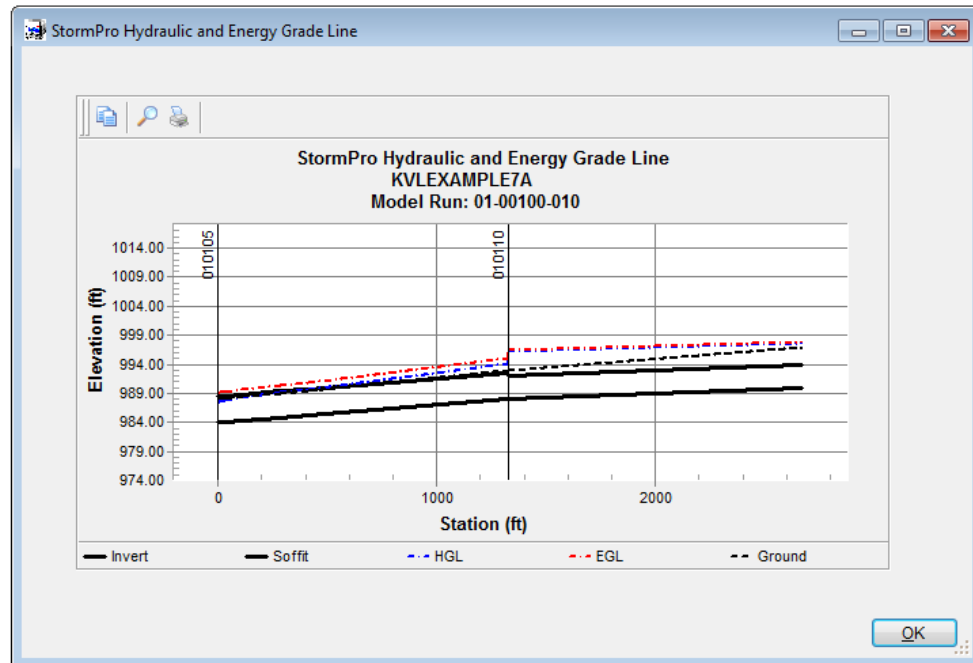
Manual Tutorial Results Run Model OK

Click **Run Model** to run the model. Click **Yes** to continue.



I – Hydrology and Storm Drainage Hydraulics

Click **Graph** to view the graph of the model results.



To view another line and/or return period, click the **View** button.

Model View

View Option

Line ID: 100

Return Period: 10

File Type: Results

Graph EGL: ☒

Info OK

Options include selecting the **Line ID**, **Return Period**, **File Type** and an option to graph the Energy Grade Line (**Graph EGL**). When selecting a **File Type** the following options are available:

“Results” will select the data from the **STORMPRO RESULTS** filtered for the selected **Line ID** and **Return Period**.

“HGL>GE” will select the data from the **STORMPRO RESULTS** filtered for the selected **Line ID**, **Return Period** and sections where the hydraulic grade line is above the ground elevation.

“Input”, “Output” and “Warning” will open the model Input, Output and Warning files, respectively (See below for examples of the Input File, Output File, and Warning File).

INPUT FILE:

```

JD
T1      Flood Control District of Maricopa County
T2      File: 01-00100-010.SPI
T3      Major Basin: 01 - Line ID: 100 - RP: 10
S0      0.00 984.00 2
R      1323.00 988.00 2      .013
JX      1328.00 988.00 1 1      .000      86.4      988.00      90.0      1      0.000
R      2671.00 990.00 1      .013
SH      2671.00 990.00 1
CD      1 4      4.00
CD      2 4      4.50

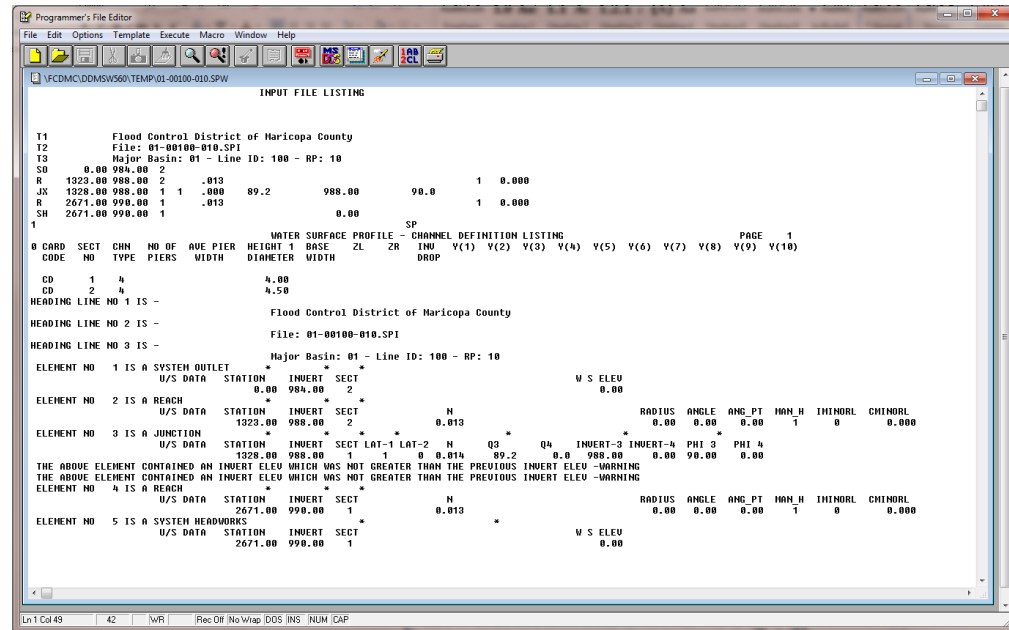
Q      47.5
  
```

OUTPUT FILE:

```

** WARNING NO. 2 ** - WATER SURFACE ELEVATION GIVEN IS LESS THAN OR EQUALS INVERT ELEVATION IN ROWS, W.S.ELEV = INU + DC
1
WATER SURFACE PROFILE LISTING
Flood Control District of Maricopa County
File: 01-00100-010.SPI
Major Basin: 01 - Line ID: 100 - RP: 10
0 STATION    INVERT    DEPTH    W.S.    Q    VEL    HEAD    ENERGY    SUPER    CRITICAL    HGT/    BASE/    ZL    NO    AUBPR
0 L/ELEV      ELEV      OF FLOW  ELEV      Q    UEL    SF AVE    HF        ELEV      DEPTH    NORM DEPTH    DIA    ID NO.    ZR    PIER
0 0.00 984.00 3.40 987.41 133.9 10.37 1.67 989.08 0.00 3.40 4.50 0.00 0.00 0 0.00
0 6.98 0.00302 3.57 987.59 133.9 9.89 0.00519 0.04 989.11 0.00 3.40 4.50 0.00 0.00 0 0.00
0 6.98 984.02 3.57 987.59 133.9 9.89 0.00470 0.15 989.11 0.00 3.40 4.50 0.00 0.00 0 0.00
0 30.87 0.00302 3.76 987.88 133.9 9.43 0.00431 0.33 989.26 0.00 3.40 4.50 0.00 0.00 0 0.00
0 37.85 984.11 3.99 988.33 133.9 8.99 0.00408 0.71 989.58 0.00 3.40 4.50 0.00 0.00 0 0.00
0 75.56 0.00302 4.28 989.15 133.9 8.57 0.00430 0.60 990.29 0.00 3.40 4.50 0.00 0.00 0 0.00
0 113.41 984.34 4.50 989.79 133.9 8.42 0.00461 4.13 990.89 0.00 3.40 4.50 0.00 0.00 0 0.00
0 173.74 0.00302 5.98 993.98 133.9 8.42 0.00332 0.02 995.09 0.00 3.40 4.50 0.00 0.00 0 0.00
0 287.14 984.87 8.07 996.07 47.5 3.78 0.022 996.29 0.00 2.07 4.00 0.00 0.00 0 0.00
0 138.67 0.00302 7.55 997.55 47.5 3.78 0.00109 1.47 997.77 0.00 2.07 4.00 0.00 0.00 0 0.00
0 425.82 985.29 7.55 997.55 47.5 3.78 0.022 997.77 0.00 2.07 4.00 0.00 0.00 0 0.00
0 897.18 0.00302 7.55 997.55 47.5 3.78 0.022 997.77 0.00 2.07 4.00 0.00 0.00 0 0.00
0 1323.00 988.00 5.98 993.98 133.9 8.42 0.00332 0.02 995.09 0.00 3.40 4.50 0.00 0.00 0 0.00
0 JUNCT STR 0.00000 8.07 996.07 47.5 3.78 0.022 996.29 0.00 2.07 4.00 0.00 0.00 0 0.00
0 1328.00 980.00 8.07 996.07 47.5 3.78 0.022 996.29 0.00 2.07 4.00 0.00 0.00 0 0.00
0 1343.00 0.00190 7.55 997.55 47.5 3.78 0.022 997.77 0.00 2.07 4.00 0.00 0.00 0 0.00
0 2671.00 990.00 7.55 997.55 47.5 3.78 0.022 997.77 0.00 2.07 4.00 0.00 0.00 0 0.00
1
  
```

WARNING FILE:



(E) Step 5 – View Backwater Results on Conveyance Facilities (*Hydraulics → Conveyance Facilities*)

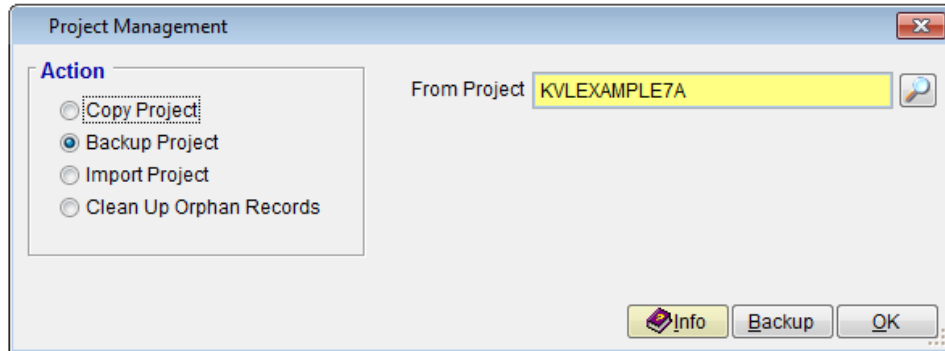
The following screen cap shows the Upstream HGL for Facility ID “010205”.

Q (cfs)	Road Depth (ft)	Upstream HGL (ft)
2 Yr 26.3		993.76
5 Yr 40.6		994.33
10 Yr 51.6		996.49
25 Yr 74.1	0.83	1000.2
50 Yr 92.1	1.03	1004.1
100 Yr 111.9	1.20	1009.4

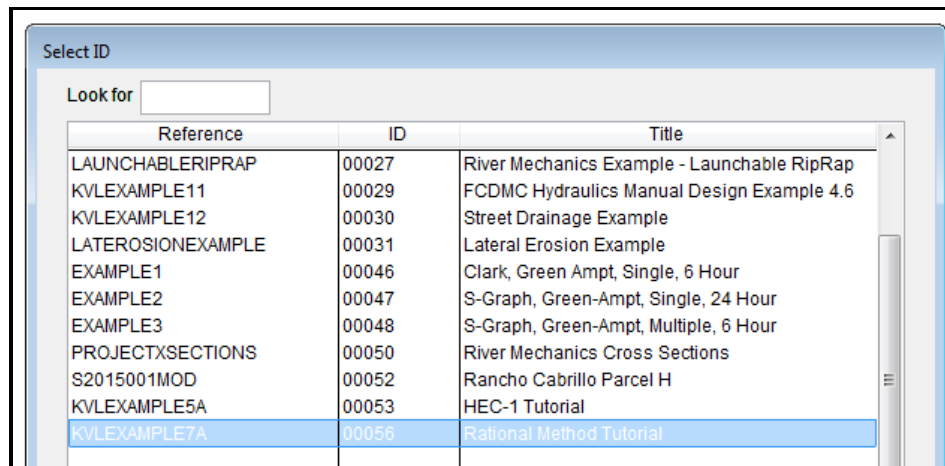
(F) Step 6 - Backup the Project

To create backup project file(s), perform the following steps:

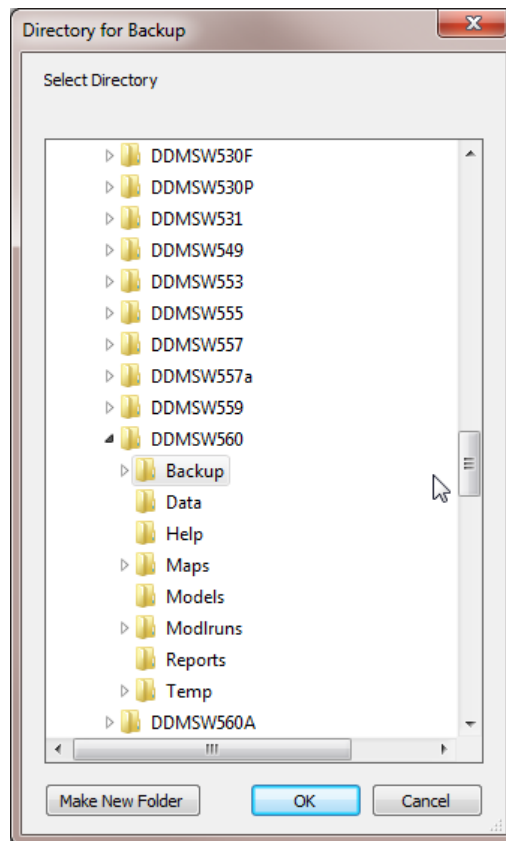
- (a) From the menu bar of the main application window, click **File** ➔ **Project Management** as shown in the following figure and the **PROJECT MANAGEMENT** window opens.



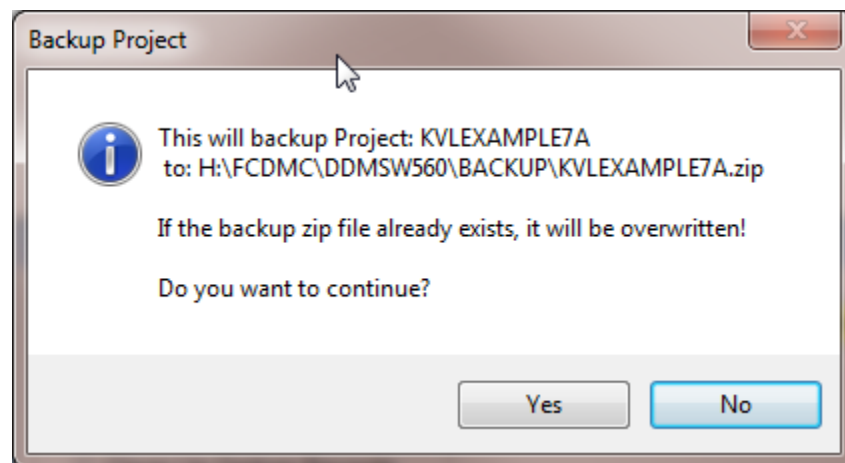
- (b) Check **Backup Project**
- (c) Click the “Magnifying Glass” button to the right of **From Project** to open the **SELECT ID** window.



- (d) Select “KVLEXAMPLE7A” and click the **OK** button to close the window.
- (e) Click **Save** on the **PROJECT MANAGEMENT** window to save the data.
- (f) Click **Backup**.
- (g) Select a folder where the backup file(s) will be saved (defaults to **Backup** sub directory)



- (h) Click **OK** to save the folder setting.
- (i) When the **BACKUP PROJECT** dialog box appears, click **Yes** to continue.

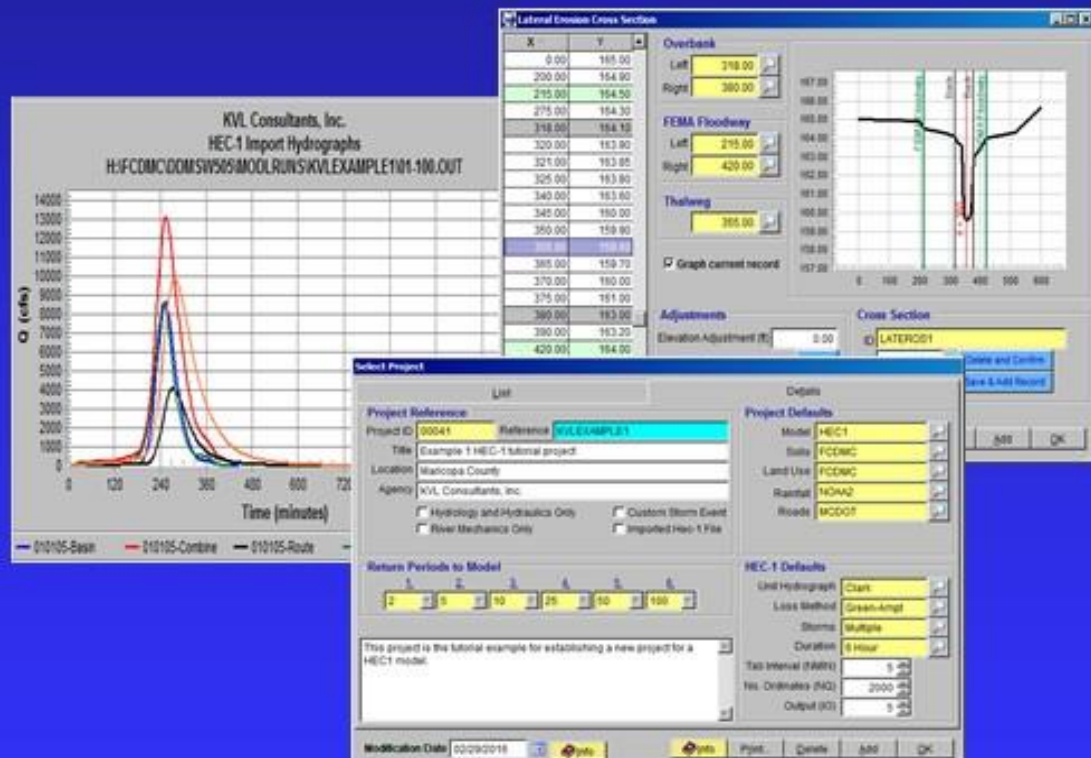


This concludes this tutorial.

APPENDIX A – DDMSW USER’S MANUAL



DDMSW User's Manual



Flood Control District of Maricopa County
2801 W Durango St, Phoenix
Arizona 85009